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Date: Wednesday, October 27, 2010 11:56AM
Subject: NSO site occupancy

Nathan,

As requested at our meeting on Monday, I've pulled together all the annual site occupancy estimates we have for NSO (see Excel spreadsheet attached).

One important point is that these estimates all come from analyses that use "all" owl detections on a site - both single owls and pairs. Thinking about it some more, this seems appropriate given the HexSim model is dealing with individual owls, not pairs specifically. I can pull together estimates for "pair occupancy" only, but that will take some time as I have to go back and output those estimates from most of these analyses and I'm not sure that's really what we want here.

I've also attached the NSO Protocol report where all these data are summarized - you can find occupancy figures for each study area here and see Table 5 or Table 7 for the "best" structure on extinction and colonization for each study area. Annual site occupancy is derived from these estimates of extinction and colonization, so that's why HJA, which had no BO effects on either of these parameters only has a "no BO" estimate of site occupancy.

Let me know if you have any questions - Bob/Eric please chime in if I've forgotten something here!

Katie

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Attachments:

NSO Annual Site Occup Data.xlsx

FWS NSO Survey Protocol Update Report_Final.pdf

Dugger et al. (2008, in review)

Year	CAS_noBO	CAS_NoBO_LCL	CAS_NoBO_UCL	CAS_BO	CAS_BO_LCL	CAS_BO_UCL
92	0.9003494	0.8724437	0.9282551	0.7112239	0.5971464	0.8253014
93	0.8720553	0.8463869	0.8977237	0.5834516	0.4503046	0.7165986
94	0.8597872	0.8319139	0.8876604	0.519273	0.3824076	0.6561383
95	0.8544678	0.8247593	0.8841763	0.4870368	0.345555	0.6285186
96	0.8521613	0.8213783	0.8829444	0.4708449	0.3239021	0.6177878
97	0.8511613	0.8198118	0.8825107	0.462712	0.3111882	0.6142357
98	0.8507276	0.8190939	0.8823613	0.4586268	0.3039045	0.6133491
99	0.8505396	0.8187672	0.8823121	0.4565749	0.2998315	0.6133184
00	0.8504581	0.8186192	0.882297	0.4555443	0.2975962	0.6134924
01	0.8504228	0.8185523	0.8822932	0.4550266	0.296386	0.6136672
02	0.8504074	0.8185222	0.8822927	0.4547666	0.2957372	0.613796
03	0.8504008	0.8185086	0.8822929	0.454636	0.2953917	0.6138802
04	0.8503979	0.8185025	0.8822933	0.4545704	0.2952087	0.613932
05	0.8503966	0.8184998	0.8822935	0.4545374	0.2951122	0.6139627
06	0.8503961	0.8184986	0.8822936	0.4545209	0.2950614	0.6139804

Olson et al. (in prep)

Year	CLE_noBO	CLE_noBO_LCL	CLE_noBO_UCL	CLE_BO	CLE_BO_LCL	CLE_BO_UCL
90	0.890391	0.8557985	0.9249835	0.6103434	0.4560912	0.7645956
91	0.8637351	0.8413129	0.8861573	0.6679425	0.6015662	0.7343189
92	0.7991457	0.744542	0.8537494	0.46927	0.3142901	0.6242498
93	0.676845	0.6158946	0.7377954	0.2139635	0.0799836	0.3479435
94	0.6790533	0.6010324	0.7570742	0.3548838	0.1939381	0.5158294
95	0.6782588	0.5966734	0.7598441	0.3690994	0.2255236	0.5126753
96	0.5744585	0.4948002	0.6541167	0.1682908	0.0631322	0.2734494
97	0.5282488	0.4435036	0.612994	0.1582436	0.0473004	0.2691868
98	0.5597322	0.4699902	0.6494741	0.2725774	0.1470216	0.3981331
99	0.5649387	0.4743645	0.655513	0.2744156	0.1555613	0.3932699
00	0.5839845	0.4936623	0.6743066	0.301076	0.1766209	0.4255311
01	0.533685	0.4461615	0.6212085	0.2029201	0.0930494	0.3127909
02	0.4925916	0.408027	0.5771563	0.1618879	0.0663894	0.2573864
03	0.4685878	0.3854516	0.5517241	0.1586832	0.067674	0.2496924
04	0.4452619	0.3625917	0.5279321	0.1489556	0.0643305	0.2335806
05	0.4457051	0.3620159	0.5293944	0.1731364	0.0845168	0.2617559

Olson et al. 2005

Year	COA_noBO	COA_noBO_LCL	COA_noBO_UCL	COA_BO	COA_BO_LCL	COA_BO_UCL
91	0.7969467	0.7464799	0.8474135	0.7265213	0.6542828	0.7987597
92	0.804848	0.7605457	0.8491502	0.7023894	0.6127959	0.7919828
93	0.8048321	0.7611574	0.8485068	0.6859714	0.5878595	0.7840832
94	0.800836	0.7576852	0.8439867	0.6722721	0.5709211	0.773623
95	0.7946514	0.7521798	0.8371231	0.6593893	0.5569032	0.7618754
96	0.7871234	0.7450454	0.8292015	0.6465681	0.5434491	0.7496872
97	0.7786639	0.7362205	0.8211073	0.6335007	0.5294224	0.737579
98	0.7694804	0.7255048	0.813456	0.6200627	0.5142248	0.7259005
99	0.7596813	0.7127222	0.8066404	0.6062095	0.4975233	0.7148957
00	0.7493259	0.6978106	0.8008412	0.5919339	0.479147	0.7047208
01	0.7384492	0.6808342	0.7960642	0.5772476	0.4590467	0.6954486
02	0.7270746	0.6619415	0.7922077	0.5621735	0.4372728	0.6870742

Olson et al. 2005

No direct BO effect on either colonization or extinction rates for HJA (through 2003)

Year	HJA	HJA_LCL	HJA_UCL
91	0.9107376	0.8717745	0.9497007
92	0.9093923	0.8731254	0.9456591
93	0.9021167	0.8685343	0.9356992
94	0.8940848	0.8638554	0.9243142
95	0.8867075	0.8589239	0.9144912
96	0.880214	0.8533057	0.9071223
97	0.8745438	0.8470048	0.9020829
98	0.8695504	0.8402866	0.8988142
99	0.8650757	0.8334036	0.8967478
00	0.861013	0.8265471	0.8954789
01	0.857315	0.8198853	0.8947446
02	0.8539045	0.8134463	0.8943627

Dugger/Anthony/Forsman/Biswell unpubl.

Year	OLY_noBO	OLY_NoBO_LCL	OLY_NoBO_UCL	OLY_BO	OLY_BO_LCL	OLY_BO_UCL
91	0.8926772	0.825524	0.9598305	0.7850962	0.6404447	0.9297478
92	0.8899439	0.8368644	0.9430234	0.7800134	0.6722895	0.8877374
93	0.8981462	0.8459899	0.9503026	0.7945724	0.6861844	0.9029605
94	0.8123981	0.7504012	0.874395	0.6513216	0.5331381	0.7695051
95	0.7609999	0.6901299	0.8318699	0.5960744	0.4863908	0.7057581
96	0.7520414	0.6861917	0.8178911	0.5933602	0.4925886	0.6941319
97	0.7899387	0.7287711	0.8511064	0.6476461	0.54409	0.7512023
98	0.8619161	0.8087653	0.9150668	0.7631718	0.6597876	0.8665561
99	0.5627685	0.4518709	0.6736661	0.3664223	0.2483223	0.4845223
00	0.6801763	0.6053548	0.7549978	0.5341088	0.4462855	0.6219321
01	0.6836254	0.6148618	0.7523889	0.5211997	0.4225838	0.6198155
02	0.6955787	0.6279892	0.7631681	0.5282766	0.4233964	0.6331568
03	0.6150889	0.5383341	0.6918437	0.4211862	0.3226583	0.5197141
04	0.5834638	0.5065788	0.6603488	0.3917432	0.3038954	0.479591
05	0.597735	0.5199369	0.6755332	0.4131924	0.3165566	0.5098283
06	0.4902335	0.3946191	0.5858478	0.3010159	0.2128369	0.3891949
07	0.4679761	0.356611	0.5793412	0.2888436	0.187682	0.3900052

Olson et al. 2005

Year	TYE_noBO	TYE_NoBO_LCL	TYE_NoBO_UCL	TYE_BO	TYE_BO_LCL	TYE_BO_UCL
91	0.6576069	0.6141647	0.7010491	0.5090269	0.3675925	0.6504613
92	0.6471335	0.6121577	0.6821093	0.4646722	0.3228491	0.6064953
93	0.6421179	0.6064932	0.6777426	0.4531302	0.3195325	0.5867279
94	0.639716	0.6026164	0.6768155	0.4501267	0.3208531	0.5794004
95	0.6385657	0.6005116	0.6766198	0.4493452	0.3217691	0.5769212
96	0.6380149	0.5994469	0.6765829	0.4491418	0.3221575	0.5761261
97	0.6377511	0.5989227	0.6765795	0.4490889	0.3222978	0.5758799
98	0.6376248	0.5986676	0.676582	0.4490751	0.3223445	0.5758057
99	0.6375643	0.5985441	0.6765845	0.4490715	0.3223593	0.5757837
00	0.6375353	0.5984845	0.6765861	0.4490706	0.3223639	0.5757773
01	0.6375214	0.5984557	0.6765872	0.4490703	0.3223653	0.5757754
02	0.6375148	0.5984419	0.6765877	0.4490703	0.3223657	0.5757749

Final Report

Estimating Northern Spotted Owl Detection Probabilities: Updating the USFWS Northern Spotted Owl Survey Protocol

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INTRODUCTION

For over 15 years, public and private organizations have been using the survey protocol for northern spotted owl (*Strix occidentalis caurina*) as recommended by the U.S. Fish and Wildlife Service (USFWS1992) for approval of habitat modification activities. Prior to implementing timber harvest activities, surveys for northern spotted owls are required to determine occupancy of this threatened species. The current protocol was developed with the best, albeit limited, information available at the time; however, more recent modeling efforts for Northern Spotted owl have provided insights that raise concerns about the efficacy and accuracy of the historic protocol. Specifically, the recent invasion of the Pacific Northwest by the barred owl (*Strix varia*), a potential competitor of the spotted owl, has had a suppression effect on spotted owl response rates (Olson et al. 2005, Crozier et al. 2006) and may be affecting occupancy dynamics of spotted owls in the landscape (Olson et al. 2005, Dugger et al. *in review*, Sovern et al. *in prep*). Therefore, survey results based on spotted owl detections when barred owls are present in the landscape may provide false or limited information about spotted owl presence and lead to inappropriate forest management activities under the Endangered Species Act.

To address this concern, unbiased estimates of the probability of detecting spotted owls with and without the presence of barred owls are needed. In addition, the current protocol indicates that if no spotted owl responses have been obtained from a site that was used by spotted owls historically after 3 years of survey, the site may be considered unoccupied. As a result, 3 years of surveys with negative results usually leads to harvesting of the historic site of a threatened species and a net loss of suitable habitat. To update this component of the current protocol, we evaluated whether 3 years of surveys were sufficient for determining that a site was truly unoccupied (and at what level of certainty). One way of answering this question was to determine the colonization rates of historic sites by spotted owls, when barred owls were detected and not detected. A second way to provide insight into this issue was to summarize the consecutive number of years sites previously occupied sites become unoccupied and then become re-occupied by spotted owls. The length of these "gaps" between occupied states provided some insight into the number of years needed to determine whether a site was likely to be occupied in the future.

Much of the information we needed to answer these questions were available as components of previous analyses (Olson et al. 2005, Dugger et al. *in review*, Sovern et al. *in review*) and in the data collected on the Demographic Study Areas for monitoring spotted owl populations. Summarization of this information will enable updates of survey protocol if needed, and inform policy decisions for habitat protection measures for historically occupied sites. Accomplishing this work will also satisfy recovery actions in the 2008 Final Northern Spotted Owl Recovery Plan (USDI, FWS 2008). The objectives of this project were:

1) Determine the probability (p) of detecting a spotted owl on a single visit, given that they are present or given the site is occupied with and without barred owl presence.
2) Determine the colonization rates of historic sites deemed unoccupied by spotted owls.

STUDY AREAS

The target population for this analysis was the population of northern spotted owls that occurred on federal and non-federal lands within the range of the species. To address our objectives, we used survey data and the associated previously completed occupancy analyses from existing northern spotted owl demography studies, including data from Cle Elum, Coast Range, H.J. Andrews, Tyee, and South Cascades. Survey data from the Olympic study area was also analyzed and results presented to augment the data from other study areas. Please see Anthony et al. (2006) for detailed descriptions of the various study areas.

METHODS

Detection and colonization rates in relation to barred owl detections were estimated using occupancy models developed by of MacKenzie et al. (2003). The application of these models to owl demography data and complete occupancy results for HJ Andrews, Tyee and the Coast range were available in Olson et al. (2005). We used the model results from Olson et al. (2005) to meet our project objectives for these areas. Models for the Cle Elum data were also available (Sovern et al. *in prep*), but data for the Olympic Peninsula was analyzed for the first time to meet this projects objectives. The sampling units for occupancy modeling were individual nesting or breeding territories, and the following methods are representative of the methods used to generate results for each of the data sets.

Survey Data

All analyses were performed on data collected annually for marked owls across a varying range of years and breeding territories depending on study area (Table 1). A standard protocol across the owl's range was used to estimate survival and productivity on each study area (Franklin et al. 1996, Lint et al. 1999). Vocal lure surveys were used to systematically search each study area for territorial owls, and 6 replicate surveys during the breeding season without owl detections (March-August) were required before concluding an area was unoccupied for a given year. Boundaries and calling points for surveys were established *a priori* and remained the same each year and both night and daytime visits are included. Survey effort was thus constant for all years and was conducted across all vegetative types and conditions. Although these survey methods were designed to document survival and productivity, they were well suited for determining occupancy rates as well (Olson et al. 2005). The general field methods for locating and banding of owls, determining sex and age, re-sighting previously marked owls and determining productivity are described by Franklin et al. (1996). Adaptation of these data for occupancy analyses are described by Olson et al. (2005).

For the purposes of this project, we were interested in detection rates and colonization probabilities for any owl, not just owl pairs, so we used analyses associated with the data set that represented occupancy by any single owl or pair of owls regardless of status (Olson et al. 2005). The number of territories surveyed for owls and included in these analyses ranged from a low of 92 at Cle Elum to a high of 147 at Olympic (Table 1). A total of 758 breeding territories over a 13-18 year period were included in these analyses.

A barred owl covariate was developed to model the effect of barred owl presence on site occupancy dynamics. A year-specific binary covariate was developed and coded as "1" if a barred owl was detected on the site during any of the surveys within a given year and “0” if not detected. This barred owl covariate was year and site specific (Olson et al. 2005). Both extinction probabilities (epsilon: ε) and colonization rates (gamma: γ) (Mackenzie et al. 2003) are interval estimates encompassing the interval from time i to time $i+1$, so there are two potential time periods at which barred owls might be detected (time i and $i+1$) that could influence extinction and colonization rates of spotted owls. In order to address this issue, we investigated the relationship between barred owl presence at time i (BO) and at time $i + 1$ (BO1) in relation to extinction and colonization of spotted owls during yearly intervals (Olson et al. 2005).

The NSO Survey Protocol working group also asked me to generate detection rates based on the proportion of territories on which barred owls were detected each year (Fig 1A-1B). In other words, the covariate used in the barred owl effect was not “0” (no barred owl) or “1” (barred owl), but some value in between, representing the mean barred owl effect across all the territories included in the analysis for South Cascades and the Olympic study areas. This value is calculated directly by MARK from the raw capture history data used in the occupancy analyses for each study area. The caution here is that these “mean” barred owl affects reflect study area-wide responses and aren’t necessarily comparable to other study areas with different barred owl densities. However for comparison purposes I graphed detection rates for all study areas and annual site occupancy rates for South Cascades and the Olympic areas with a study-area specific, mean annual barred owl response.

We also used a simple empirical approach to determine how many years of surveys with no spotted owls detected in a breeding territory are needed before a site can be considered truly unoccupied and thus, released for harvest. This approach resulted in a simple frequency distribution of the number of consecutive years that an owl was not detected on a site, between years of occupancy. This allowed us to determine the longest length of time a spotted owl might not be detected on a site, before occupancy was confirmed. It is important to remember that the probability of occupancy is the result of occupancy dynamics (extinction and colonization) that occur between years, whereas the probability of detection is associated with a specific year's surveys. Thus, the empirical visit history data for spotted owl sites reflected both the probability of occupancy and detection probabilities. A site for which an owl was never detected within a season may have been unoccupied, or occupied, but the owl was never detected so we can't determine true occupancy state without models that allow us to estimate detection probabilities and annual site occupancy separately (MacKenzie et al. 2006).

The crew leaders for Cle Elum, HJ Andrews, the Coast Range, Tyee, South Cascades and Klamath summarized the data in two ways. First, a site must be occupied by a resident, territorial owl or pair (a historically "occupied" site) and then the length of time (years) during which no spotted owl was detected (across all multiple visits within a year) was counted until 1) another resident owl or pair was detected (R to R), or 2) any spotted owl was detected, including non-territorial birds, those that were moving in the landscape, neighboring birds, etc., (R to A). The frequency of consecutive years of when an owl was not detected were then plotted as 1, 2, 3, $\geq$2 and $\geq$3 years. The $\geq$2 and $\geq$3 year categories were included to reflect the overall proportion of sites where spotted owls were not detected for more than 2, or 3 consecutive years. This provided insight into whether the current 2-year protocol required to clear a site for harvest was adequate (i.e., what was the proportion of sites where spotted owls were not detected for 2 or more, or 3 or more years but were later occupied).

The number of territories that included $\geq$1 year when spotted owl were not detected (i.e., a "gap") ranged from 38 on Cle Elum to 153 on Tyee study areas (Table 2). The number of additional territories that were either continuously occupied through 2008 or occupied continuously up to some previous year, but owls have since not been detected (so they did not contain a "gap" according to our definition), ranged from a low of 7 on Cle Elum to 69 on the Klamath area (Table 2).

Model Development

We used occupancy models developed by MacKenzie et al. (2003) for open populations to estimate detection and colonization probabilities. These models provide estimates of site occupancy for the first primary sampling period (Ψ_1), extinction probability (ε), and colonization probability (γ) for primary sampling periods, and detection probability (ρ_{tj}) given presence in survey *j* (secondary samples within seasons) within primary sampling period *t* (MacKenzie et al. 2003). For this project we were primarily interested in detection rates and colonization probabilities, but it was important to determine the best model for colonization rates in relation to extinction rates, and additional data requests during the middle of this project resulted in the generation of extinction rates and annual site occupancy rates. Thus, we modeled both colonization and extinction with variable time (t) effects, time trends (T) and barred owl (BO) detections. All models were generated and occupancy parameters estimated using Program MARK (White and Burnham 1999). Colonization probabilities were developed for intervals between year *i* and year $i + 1$, and they were conditional on status at year *i* (time prior to interval)

(MacKenzie et al. 2003). For this project, it's important to understand that colonization probability in these models is defined as "the probability that an unoccupied site at time *i*, becomes occupied at time *i+1*. Thus, 1-γ, is the probability that an unoccupied site at time *i*, remains unoccupied at time *i+1* (MacKenzie et al. 2006). Extinction rates (ε_i) are defined as the probability that occupied sites at time *i*, becomes unoccupied at time *i+1*, and 1-ε_i, is the probability that an occupied site at time *i*, remains occupied at time *i+1*.

Estimates of annual site occupancy are derived parameters generated using extinction and colonization rates and the following equation from MacKenzie et al. (2003):

$$\hat{\Psi}_t = \hat{\Psi}_{t-1}(1-\hat{\varepsilon}_{t-1}) + (1-\hat{\Psi}_{t-1})\,\hat{\gamma}_t$$

These derived estimates, standard errors and 95% confidence limits are now provided by as output in Program MARK.

We modeled detection probabilities with time trends (T, lnT, TT) and variable time effects (t) on between- and within-year detection rates and the presence of barred owls (BO, BO1) on between year detection rates. The best model for detection probabilities then was used for modeling colonization and extinction rates. During this stage of modeling we investigated time–specific (t) and time trend (T, lnT, TT) models on extinction and colonization probabilities. Barred owl covariates were then added to the best time-specific model, and we present the detection and colonization probabilities from the best model.

Model Selection

In the original analyses for some of these study areas (i.e., Olson et al. 2005, Dugger et al. *in review*, Sovern et al. *in prep*), information theoretic approaches

(Burnham and Anderson 2002) were used to select the best model at each analysis stage. The corrected version of Akaike's Information Criterion (AIC_c) for small sample sizes and Akaike weights were used to rank models (Burnham and Anderson 2002), and in most cases, the "best" model was the model with the lowest AIC_c. In addition, 95% confidence intervals for slope coefficients (β_i) were also used to evaluate the strength of evidence for the importance of time trends and the barred owl covariate in competing models (<2 AICc values). For this reason, the "best" model presented here was competitive sometimes, but did not have the lowest AIC_c. This model selection approach was also used to select the best models for the occupancy analysis of the Olympic study area, which was completed specifically for this project.

RESULTS

Detection rates

The proportion of spotted owl territories on which barred owls have been detected has increased steadily on most of the study areas, particularly on Olympic, Coast Range, HJ Andrews, and Tyee study areas (Figures 1A-1B). For all study areas included in this analysis, the site-specific, annual barred owl covariate had strong negative effects on detection rates of northern spotted owls (Table 3) and was always included in the best model for detection probabilities. In addition, the barred owl effect was always negative and statistically significant except for the South Cascades study area prior to 1998 (Table 3), when there was little or no barred owl effect, likely because barred owls were not yet common on the study area prior to that time (Figure 1B).

Detection rates varied annually both when barred owls were detected and when they were not, for all study areas except Cle Elum (Figures 2A - 2F). Detection probabilities were consistently lower when barred owls were detected in the breeding territories of spotted owls. In addition, there was an interaction between the barred owl effect and time for the South Cascades. Within season detection rates for South Cascades exhibited a linear trend, which was independent between years, and subsequently some of the confidence limits on these within season detection rates were very large. For this reason, we chose to present the estimates from the model with constant within season detection rates (mean across entire season) (Figure 2F).

The current survey protocol calls for 6 visits to a site if a 1-year survey is conducted. One of the objectives of our analyses was to determine how many visits within a season are required to detect a spotted owl with 95% certainly given it is present, and what affect barred owls have on these detection rates. Consequently, we calculated an overall annual detection rate (p^*) from the per visit detection rates estimated with our robust design occupancy models. The overall, annual detection rate p_i^*, can be calculated from the visit-specific p_{ij} as follows:

$$p_i^* = 1 - [(1 - p_{i1})(1 - p_{i2})(1 - p_{i3}) \ldots\ldots\ldots (1 - p_{ij})]$$

For simplicity, let's assume p_{ij} are constant within season (i.e. $p_{i1} = p_{i2} = p_{i3} = p_{i.}$). Thus, if we want to know the minimum per visit detection rate required to detect a spotted owl at least one time during a season if it's present with 95% certainty, under the current protocol (i.e., 6 visits per season), we can solve the following equation for $p_{i.}$:

$$0.95 = 1 - (1 - p_{i.})^6$$

$$p_{i.} \cong 0.40$$

Thus, in order to satisfy the current 6-visit protocol for 1-year surveys, the per-visit detection rate must be $\geq$0.40. Using this equation we computed the p_i^* for any particular combination of p_{ij} and number of visits within a year for each study area (Tables 4A – 4F). For most study areas, 4 to 8 visits per year were needed to detect spotted owls with 95% certainty if they were present (Tables 4A – 4F). However, lower confidence limits on detection rate estimates for South Cascades and the Olympic study areas indicated that 9 or more visits per year were needed to detect spotted owls when present and when barred owls were also detected (Table 4A-4F). Detection rates with confidence limits less than or equal to 0.40 were observed for 8 of 18 years on the Olympic (Figure 2A), 2 of 13 years on Tyee (Figure 2E), 4 of 16 years on South Cascades (Figure 2F), but were never observed for Cle Elum (Figure 2B), HJ Andrews (Figure 2C) or the Coast Range study areas (Figure 2D).

Estimates of population level detection rates reflecting the mean proportion of territories where barred owls were detected each year, were generally >0.40 and in most cases >0.50 (Figures 3A-3F) except for three years on the Olympic study area (Figure 3A). Thus, 4 to 5 visits may be enough each year to detect spotted owls with 95% certainty if barred owls are detected at the rate reflected by these mean responses. However, it's unclear what "true" densities of barred owls were on these demographic study areas, or how negatively biased detections of barred owls were, given that the survey protocol focused on spotted owls. It's also important to remember, that densities of spotted owls and detection rates on demography study areas were likely higher than we might expect on general managed forest lands. Higher overall habitat quality, a more focused survey protocol that includes historical knowledge of owl site centers, and higher effort expended to find owls each year, likely means detection rates in a managed forest landscape are lower than these "mean response" rates shown here (see A.J. Kroll's analyses of Weyerhaeuser managed lands). This is probably particularly true and the discrepancy exacerbated when barred owls are detected.

Colonization Rates

The second objective of this project was to determine colonization rates of historic northern spotted owl sites and how barred owls affect these colonization rates. It is important to remember the exact definition of colonization rate (see methods above) as an interval rate (a measure of change between primary survey periods). Thus, colonization rates reflect a change in the occupancy status of a currently unoccupied site from one year to being occupied the next.

Barred owl detections generally had a stronger effect on extinction rates compared to colonization rates, but a negative effect of barred owls on colonization was observed for the South Cascades study area (Table 5; Figure 4E). Colonization rates for the Olympic and Coast Range study areas declined during the study, and the general time variation (t) for Cle Elum also suggested declining colonization rates. These declining colonization rates may reflect indirect barred owl effects (Figure 4A, 4B, 4D). We observed strong barred owl effects on extinction rates for the Tyee study area, but colonization rates were constant relative to time and barred owl presence (Table 5; Figures 4C). Colonization rates were variable among study areas (Table 5), and the most recent estimates were very low on some cases (i.e., Olympic, Cle Elum, Coast Range; Table 5), particularly when barred owls were detected at South Cascades (Table 5).

The complement of colonization rate is $1-\gamma$, or the probability that an unoccupied site remains unoccupied between time i and time $i+1$. This parameter may be more useful in determining the probability that a site which has been unoccupied for 3 years will remain unoccupied (current FWS survey protocol). First, remember that the probability of colonization (γ) and the probability of remaining uncolonized (1-γ) are interval estimates, so 2 colonization rates reflect 3 years of surveys, 3 colonization rates reflect 4 years of surveys, etc. Under the current 3-year survey protocol, we can ask what the probability of a site remaining unoccupied must be during the 2 intervals associated with 3 years of surveys in order to achieve a 95% overall probability of remaining unoccupied for 3 years. We can use a derivation of the equation we used to compute overall detection rates (p_i^*) to answer this question:

$$1 - \gamma_i^* = 1 - [(\gamma_{i1})(\gamma_{i2})(\gamma_{i3}) \ldots \ldots \ldots (\gamma_{ij})]$$

If we assume constant colonization rates over time, and 95% probability that a site remains unoccupied over a given set of intervals (*k*) with given $\gamma_{i.}$ then we can solve the following equation for *k*:

$$0.95 = 1 - (\gamma_{i.})^k$$

With only two colonization rates based on 3 years of surveys, you can only assume an unoccupied site will remain unoccupied with 95% probability if colonization rates (γ) $\leq$ 0.20 for those 2 intervals (Table 6). Colonization rates this low (estimates with 95% confidence intervals that overlapped 0.20) were observed for the Olympic during 2003 – 2006, Cle Elum from 1993 – 2002, Coast Range during 1999 – 2002 and South Cascades when barred owls are detected (Figures 4A, 4B, 4D, 4E). However, in most years, when colonization rates were > 0.20, the probability that unoccupied sites remain unoccupied through 3 years was < 0.95. This suggests that even 3 years of surveys is not enough to be certain an unoccupied site will remain unoccupied and can be cleared for harvest.

Extinction Rates

The detection of barred owls on spotted owl territories increased extinction rates of spotted owls consistently across all 6 study areas except for HJ Andrews (Table 7; Figures 5A – 5F). When barred owls were not detected, extinction rates were generally < 20%, except for a few years on the Olympic study area. In contrast, when barred owls were detected, extinction rates generally doubled (Figures 5A – 5F) and were as high as 0.41 on Tyee and 0.64 in one year on the Olympic.

Annual Site Occupancy

Annual site occupancy on all study areas except HJ Andrews, directly reflect the affects of barred owl detections because extinction rates increased at the Olympic, Cle Elum, Coast Range, Tyee and South Cascades study areas in relation to barred owl detections (Table 5). In addition, barred owls also decreased colonization rates for the South Cascades, further affecting spotted owl occupancy (Table 5). Although we could not detect an affect of barred owl detections on extinction and colonization rates at HJ Andrews, extinction rates did exhibit an increasing trend over time, likely related to the affect of barred owls (Table 5). This also resulted in a slight declining trend in occupancy on the HJ Andrews (Figure 6C).

Occupancy rates exhibit high annual variation for the Washington study areas (OLY, CLE), and range from approximately 90% on both the Olympic and Cle Elum areas when barred owls are not detected early in the study, to below 50% in recent years (Figures 6A, 6B). Occupancy rates on Cle Elum since the late 1990's when barred owls are detected are generally very low (<30%; Figure 6B). Annual site occupancy on HJ Andrews is generally very high (>80%), but in addition to the Coast Range, exhibits a declining trend (Figures 6C, 6D. This decline in occupancy rates is slight on HJ Andrews (Figure 6C), but stronger on the Coast Range, which includes a barred owl effect on extinction rates (Figure 6D). Annual site occupancy is the most stable over time for Tyee and South Cascades study areas, although both exhibit strong barred owl effects and occupancy rates when barred owls are detected are about 50% (Figures 6E, 6F). When barred owls are not detected, occupancy rates on South Cascades can be very high (>80%; Figure 6F), comparable to HJ Andrews.

Empirical Approach

As we might expect, the number of consecutive years when spotted owls were not detected on was usually 1 or 2 years, no matter whether the gap ended with the detection of a territorial owl or any spotted owl detection (Figures 7A – 7F). However, the frequency of consecutive years with no spotted owl detections greater than or equal to 3 years followed by confirmed occupancy was significant for Cle Elum (20%), the Coast Range (23%), and Tyee (28%) study areas (Figures 8A –85F). These results indicate that 3 years of surveys are not sufficient to determine whether a historical owl site is truly unoccupied or will never be unoccupied in the future, since spotted owls are eventually detected on 20 – 30% of these sites after 3 consecutive years of no detections. For some of the study areas (CLE, HJA, KLA, CAS) owl detections were observed after 7-8 consecutive years of no detections. Occupancy was re-confirmed after > 10 consecutive years without spotted owl detections on the COA and TYE study areas (Figures 7C, 7D). For historically occupied sites, it's probably not appropriate to ever consider a site incapable of being occupied if there have been no habitat changes. Conversely, allowance of habitat modifications will likely cause the site to become permanently "extinct".

SUMMARY AND DISCUSSION

Detection rates for northern spotted owls were variable both within and among years on some study areas and were significantly lower when barred owls were detected. Summaries of our current occupancy analyses suggest the per-visit detection rate for most study areas in most years are greater than 0.40, which suggests the 6-visit protocol for one year of surveys is likely still adequate to detect spotted owls if they are present with 95% confidence. However, the current analyses for several of these study areas only includes data through 2002 (HJ Andrews, Coast Range, Tyee), and the proportion of barred owls detected on spotted owl territories has continued to increase on these areas. This likely means the effect of barred owls on spotted owl detections is stronger on some of these study areas now, compared to the time frame of this analysis. This contention is supported by the fact that the analyses with the most recent data (Olympic and South Cascades) exhibit some of the lowest detection rates observed when barred owls were also detected. This is also likely the reason we didn't see strong barred owl affects on colonization rates for HJ Andrews, Coast Range and Tyee. A re-analysis using data through 2008, which would reflect an increased proportion of territories with barred owls detected, would likely reveal stronger effects of barred owls on colonization rates. The declining time trends on colonization rates for the Olympic and Coast Range study areas also may reflect barred owl interference, and the most recent colonization rates should be considered particularly relevant when considering survey protocol revision. Finally, the current surveys were designed to detect spotted owls only, so barred owl detections were incidental and not part of a focused survey protocol. Thus, it's likely we underestimated the presence of barred owls (D. Wiens, pers. comm.) and possibly the effect of barred owls on detection and colonization rates. Thus, the estimated affects of barred owls on colonization rates herein were likely conservative.

Our occupancy modeling approach (MacKenzie et al. 2003) to generate estimates of detection rates and occupancy parameters does have some limitations with regards to how these estimates can be applied to the current survey protocol. We have provided specific information regarding detection and colonization rates, as defined and outlined in our initial objectives. However, one of the practical questions associated with the estimation of colonization rates, is whether 3 years of surveys with no spotted owl detections are enough to determine that a site is likely not to be occupied at some time in the future. Alternatively, what is the probability that a site with no spotted owl detections for 3 years is truly unoccupied and likely to remain unoccupied? These questions are much harder to answer within the framework of occupancy modeling and in part the reason we also used an empirical approach to summarize the raw detection data. The occupancy models we have used here are based on frequentist statistics, which means the probabilities and precision of the estimates are based on a "sample" of territories, and are not directly applicable to predicting an outcome for a single territory or stand. The estimates and confidence intervals we have generated reflect the confidence that if we were to repeat our sampling many times, 95% of the confidence limits we computed would include the true population parameter. Thus, these results do not translate directly into a detection or colonization probability associated with a single stand or territory. While these results can be used to guide revision of the FWS survey protocol, one should be aware of the specific definitions of the parameters and careful not to extrapolate the estimates beyond an appropriate statistical framework.

The most difficult question to answer in regards to the FWS Northern Spotted Owl Survey Protocol is whether 3 years of surveys on a site with no spotted owls detected means a site is truly unoccupied or will never be re-occupied and can be approved for harvest or other activities that might adversely affect northern spotted owls. Our estimates of annual colonization rates and the summary of empirical data, indicated that 3 years of surveys were not sufficient to conclude that a site historically occupied by spotted owls, but then unoccupied (or at least a spotted owl is not detected), will never be occupied in the future. Essentially, if colonization rates on any of these sites are greater than zero, which was the case for all study areas in this analysis, then there is some probability that a currently unoccupied site will be occupied in the future, assuming that the habitat has not impacted negatively. We recommend that the Fish & Wildlife Service review the 3-year protocol and strongly consider an increase in the number of years of no occupancy before the site is approved for timber harvest. Basically, the current protocol is a prescription for continued habitat loss and decline of spotted owl breeding populations.

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Table 1: The number of years and territories included in the occupancy analyses presented in this study for each northern spotted owl demography area.

Study Area (acronyms)	Study Duration	Number of Territories
Olympic (OLY)	1990 - 2007	147
Cle Elum (CLE)	1989 - 2005	92
HJ Andrews (HJA)	1990 - 2002	125
Coast Range (COA)	1990 - 2002	146
Tyee (TYE)	1990 - 2002	145
South Cascades (CAS)	1991 - 2006	103

Table 2: The number of territories used in the summary of empirical annual detection history data and the number of territories not included because they did not include a defined “gap” in spotted owl detections.

Study Area	≥1 Gap	Continuously Occupied
CLE	38	7
HJA	78	44
COA	145	24
TYE	153	19
KLA	87	69
CAS	87	19

Table 3: Slope coefficients ($\hat{\beta}$) and 95% confidence limits for the barred owl effect from the best model structure on Northern Spotted Owl between season detection rates for each study area. Within season effects follow between season effects, additive effect denoted with "+" and interactions by "*".

Study Area (acronyms)	Best Model	$\hat{\beta}$	95% Confidence Limits
Olympic (OLY)	p(BO + t, TT)	-0.95	-1.13 to -0.77
Cle Elum (CLE)	p(BO, .)	-1.35	-1.67 to -1.03
HJ Andrews (HJA)	p(BO + t, .)	-1.14	-1.47 to -0.82
Coast Range (COA)	p(BO + t, .)	-0.83	-1.01 to -0.65
Tyee (TYE)	p(BO + t, .)	-0.87	-1.21 to -0.53
South Cascades (CAS)	p(BO*t, T)		
	1991	-0.10	-350.33 to 350.13
	1992	1.18	-0.93 to 3.29
	1993	0.18	-0.87 to 1.24
	1994	0.57	-1.03 to 2.18
	1995	-0.34	-2.09 to 1.41
	1996	-0.74	-2.80 to 1.32
	1997	-0.79	-1.98 to 0.40
	1998	-1.22	-2.35 to -0.10
	1999	-0.90	-1.69 to -0.11
	2000	-1.68	-2.46 to -0.90
	2001	-0.86	-1.73 to 0.01
	2002	-1.28	-1.82 to -0.74
	2003	-2.90	-3.76 to -2.04
	2004	-3.19	-4.20 to -2.17
	2005	-0.75	-1.44 to -0.06
	2006	-2.24	-2.95 to -1.53

Table 4: The probability of detecting a spotted owl on a territory where a barred owl is detected (p_i*), for the highest, lowest and mean visit-specific detection rates (p_{ij}) observed across all the years in each analysis for a) Olympic, b) Cle Elum, c) HJ Andrews, d) Coast Range, e) Tyee, and f) South Cascades study areas. In all cases, detection rates presented are constant within years, so overall detection probabilities (p_i*) increase directly in relation to the number of visits and a range in these probabilities from 1 to 10 visits is presented for each study area.

a) Olympic

OLY – p (BO+t, .) – Estimates of "lowest" and "highest" p_{ij} reflect model with constant within season detection rates (annual variation only). Best model includes a time trend on detection rates within season [p (BO+t, TT)].

	Lowest p_{ij} (SE, 95% CI)	Highest p_{ij} (SE, 95% CI)	Mean[1] p_{ij}
	0.16 (0.03, 0.12-0.22)	0.49 (0.04, 0.42-0.57)	0.36 (0.02, 0.33 – 0.40)
Visit #	p_i*	p_i*	p_i*
1	0.16	0.49	0.36
2	0.29	0.74	0.59
3	0.41	0.87	0.74
4	0.50	0.93	0.83
5	0.58	**0.97**	0.89
6	0.65	**0.98**	0.93
7	0.71	**0.99**	**0.96**
8	0.75	**1.00**	**0.97**
9	0.79	**1.00**	**0.98**
10	0.83	**1.00**	**0.99**

[1] Mean reflects MARK estimates from model with no annual variation [p(BO)] which reflects a mean value across years. Estimate reflects the positive detection of a barred owl.

b) Cle Elem

CLE – best model: p (BO, .) – no annual variation, so p_i* for upper and lower confidence limit is included in addition to estimate of p_{ij}

	p_{ij} (Lower Confidence Limit)	p_{ij} (SE)	p_{ij} (Upper Confidence Limit)
	0.42	0.49 (0.04)	0.57
Visit #	p_i*	p_i*	p_i*
1	0.42	0.49	0.57
2	0.66	0.74	0.82
3	0.80	0.87	0.92
4	0.89	0.93	**0.97**
5	0.93	**0.97**	**0.99**
6	**0.96**	**0.98**	**0.99**
7	**0.98**	**0.99**	**1.00**
8	**0.99**	**1.00**	**1.00**
9	**0.99**	**1.00**	**1.00**
10	**1.00**	**1.00**	**1.00**

c) HJ Andrews

HJA – best model: p (BO + t, .)

	Lowest p_{ij} (SE, 95% CI)	Highest p_{ij} (SE, 95% CI)	Mean[1] p_{ij}
	0.33 (0.04; 0.25 – 0.42)	0.52 (0.05; 0.42 – 0.61)	0.40 (0.04; 0.33 – 0.48)
Visit #	p_i*	p_i*	p_i*
1	0.33	0.52	0.40
2	0.55	0.77	0.64
3	0.70	0.89	0.78
4	0.80	**0.95**	0.87
5	0.87	**0.98**	0.92
6	0.91	**0.99**	**0.95**
7	0.94	**0.99**	**0.97**
8	**0.96**	**1.00**	**0.98**
9	**0.97**	**1.00**	**0.99**
10	**0.98**	**1.00**	**0.99**

[1] Mean reflects MARK estimates from model with no annual variation [p(BO)] which reflects a mean value across years. Estimate reflects the positive detection of a barred owl.

d) Coast Range

COA – best model: p (BO + t, .)

	Lowest p_{ij} (SE, 95% CI)	Highest p_{ij} (SE, 95% CI)	Mean[1] p_{ij}
	0.38 (0.04; 0.31 – 0.45)	0.52 (0.03; 0.46 – 0.59)	0.46 (0.02; 0.42 – 0.50)
Visit #	p_i*	p_i*	p_i*
1	0.38	0.52	0.46
2	0.62	0.77	0.71
3	0.76	0.89	0.84
4	0.85	**0.95**	0.92
5	0.91	**0.98**	**0.95**
6	0.94	**0.99**	**0.98**
7	**0.97**	**0.99**	**0.99**
8	**0.98**	**1.00**	**0.99**
9	**0.99**	**1.00**	**1.00**
10	**0.99**	**1.00**	**1.00**

[1] Mean reflects MARK estimates from model with no annual variation [p(BO)] which reflects a mean value across years. Estimate reflects the positive detection of a barred owl.

e) Tyee

TYE – best model: p (BO + t, .)

	Lowest p_{ij} (SE, 95% CI)	Highest p_{ij} (SE, 95% CI)	Mean[1] p_{ij}
	0.31 (0.04; 0.24 – 0.40)	0.45 (0.05; 0.36 – 0.55)	0.37 (0.04; 0.30 – 0.45)
Visit #	p_i*	p_i*	p_i*
1	0.31	0.45	0.37
2	0.52	0.70	0.60
3	0.67	0.83	0.75
4	0.77	0.91	0.84
5	0.84	**0.95**	0.90
6	0.89	**0.97**	0.94
7	0.93	**1.00**	**0.96**
8	**0.95**	**1.00**	**0.98**
9	**0.97**	**1.00**	**0.98**
10	**0.98**	**1.00**	**0.99**

[1] Mean reflects MARK estimates from model with no annual variation [p(BO)] which reflects a mean value across years. Estimate reflects the positive detection of a barred owl.

f) South Cascades

CAS – p (BO*t, .) – Estimates of "lowest" and "highest" p_{ij} reflect model with constant within season detection rates (annual variation only). Best model also includes a time trend on detection rates within season [p (BO*t, T)].

	Lowest p_{ij} (SE, 95% CI)	Highest p_{ij} (SE, 95% CI)	Mean[1] p_{ij}
	0.10 (0.05; 0.04 – 0.23)	0.88 (0.17; 0.46 – 0.98)	0.29 (0.02; 0.42 – 0.50)
Visit #	p_i*	p_i*	p_i*
1	0.10	0.88	0.29
2	0.19	**0.99**	0.50
3	0.27	**1.00**	0.64
4	0.34	**1.00**	0.75
5	0.41	**1.00**	0.82
6	0.47	**1.00**	0.87
7	0.52	**1.00**	0.91
8	0.57	**1.00**	0.94
9	0.61	**1.00**	**0.95**
10	0.65	**1.00**	**0.97**

[1] Mean reflects MARK estimates from model with no annual variation [p(BO)] which reflects a mean value across years. Estimate reflects the positive detection of a barred owl.

Table 5: Colonization rate estimates (γ) and standard errors (SE) for Northern Spotted Owls from the best model for each study area. A range of estimates from high to low is presented for those areas with general time effects (t), linear time trends (T), or barred owl (BO or BO1) effects. Additive effect denoted with "+" and interactions by "*".

Study Area (acronyms)	Best Model	γ (SE)
Olympic (OLY)	ε(BO1 + t) γ(T)	0.67 (0.06) to 0.15 (0.03)
Cle Elum (CLE)	ε(BO1) γ(t)	0.50 (0.18) to 0.09 (0.05)
HJ Andrews (HJA)	ε(lnT) γ(.)	0.55 (0.06)
Coast Range (COA)	ε(BO1) γ(T)	0.42 (0.06) to 0.21 (0.04)
Tyee (TYE)	ε(BO) γ(.)	0.33 (0.02)
South Cascades (CAS)	ε(BO1) γ(BO)	0.48 (0.04) vs. 0.23 (0.07)

Table 6: The probability that an unoccupied Northern Spotted Owl site remains unoccupied $(1-\gamma)^*$ over a given set of intervals (*k*), associated with *k+1* years of surveys, for a given constant annual colonization rate (γ)

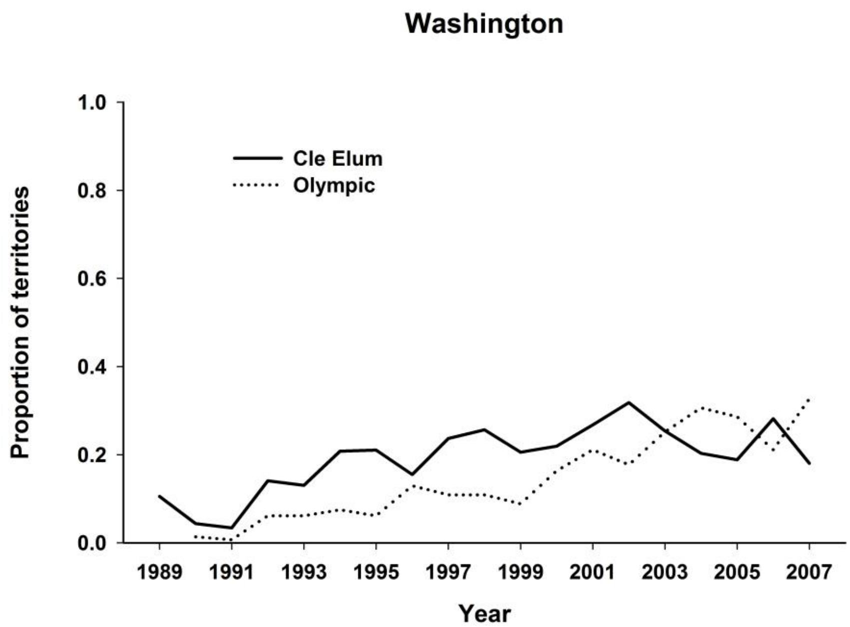
	Number of Intervals (*k*)				
γ	2	3	4	5	6
0.1	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**
0.2	**0.96**	**0.99**	**1.00**	**1.00**	**1.00**
0.3	0.91	**0.97**	**0.99**	**1.00**	**1.00**
0.4	0.84	0.94	**0.97**	**0.99**	**1.00**
0.5	0.75	0.88	0.94	**0.97**	**0.98**
0.6	0.64	0.78	0.87	0.92	**0.95**
0.7	0.51	0.66	0.76	0.83	0.88
0.8	0.36	0.49	0.59	0.67	0.74
0.9	0.19	0.27	0.34	0.41	0.47

Table 7: Extinction rate estimates (ε) and standard errors (SE) for Northern Spotted Owls from the best model for each study area. A range of estimates from low (no BO) to high (BO effect) is presented for each area with a barred owl effects. Additive effect denoted with "+" and interactions by "*".

Study Area (acronyms)	Best Model	γ (SE)
Olympic (OLY)	ε(BO1 + t) γ(T)	No BO: 0.02 (0.02) to 0.41 (0.07) BO: 0.05 (0.06) to 0.64 (0.08)
Cle Elum (CLE)	ε(BO1) γ(t)	0.09 (0.05) vs. 0.15 (0.01)
HJ Andrews (HJA)	ε(lnT) γ(.)	0.04 (0.02) to 0.10 (0.07)
Coast Range (COA)	ε(BO1) γ(T)	0.09 (0.01) vs. 0.18 (0.04)
Tyee (TYE)	ε(BO) γ(.)	0.19 (0.01) vs. 0.41 (0.11)
South Cascades (CAS)	ε(BO1) γ(BO)	0.09 (0.01) vs. 0.27 (0.06)

Figure 1: The proportion of Northern Spotted Owl territories on which barred owls have been detected for study areas in a) Washington and b) Oregon. All proportions from data sets used in analysis of survival and reproductive rates in Forsman et al. (*in review*) except for CAS and OLY, where proportions were calculated directly from raw visit history data used in the occupancy analyses presented here.

a).



b).

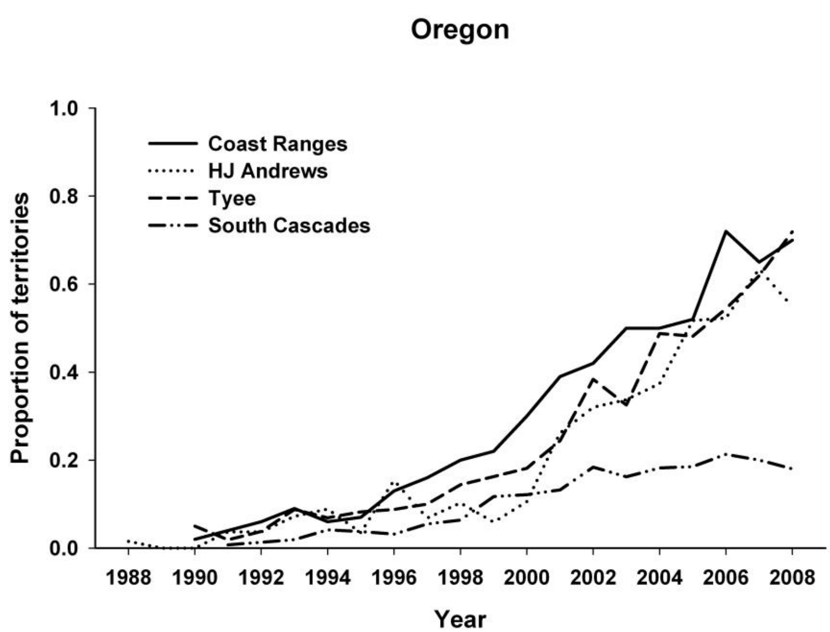
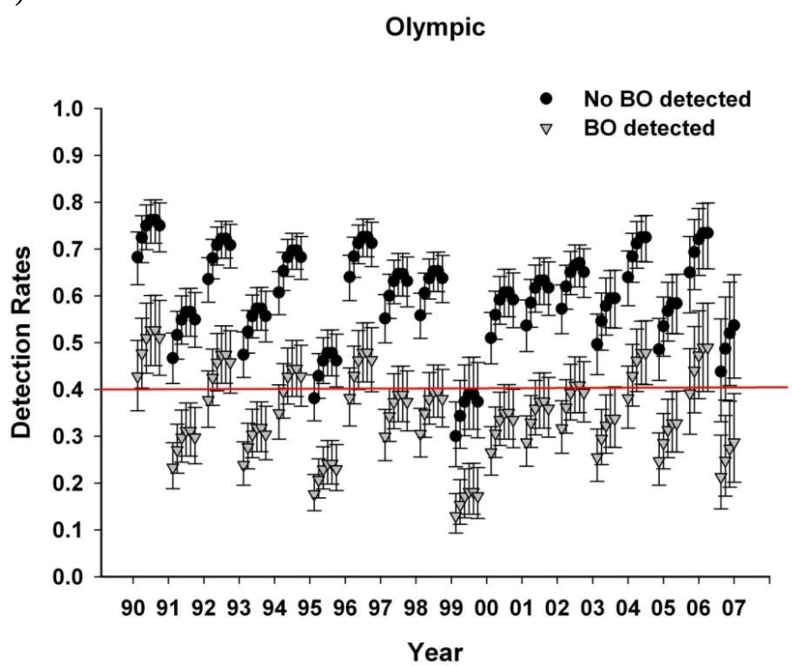
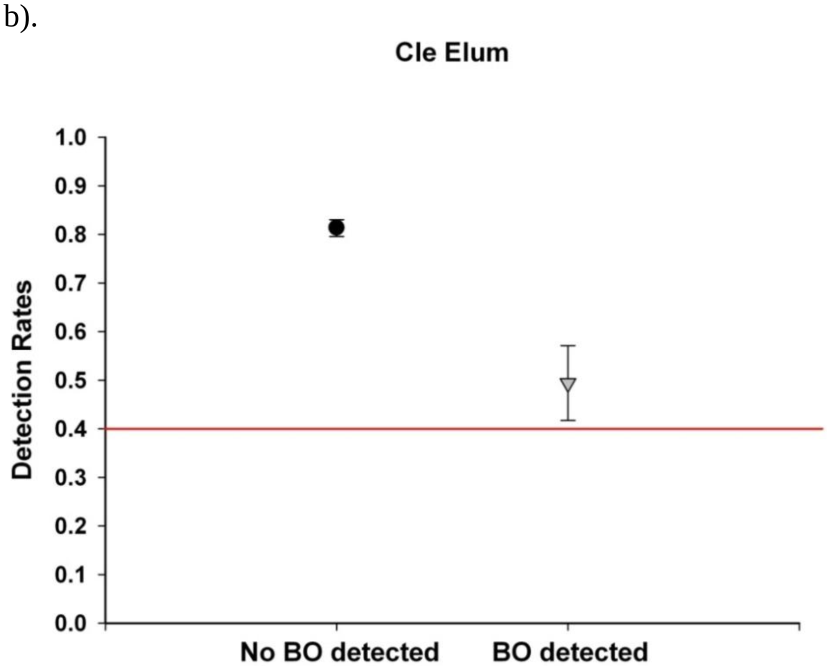


Figure 2: Estimates of detection probabilities with 95% confidence limits from the best models when barred owls are detected and when they are not for a) Olympic, b) Cle Elum, c) HJ Andrews, d) Coast Range, and e) Tyee study areas. A model with constant within season detection rates and the best between season structure [p(BO*t,.)] was used to generate estimates and confidence intervals for the f) South Cascades study area. The red line denotes the minimum p_{ij} required to determine a spotted owl is present given 6 visits per year.

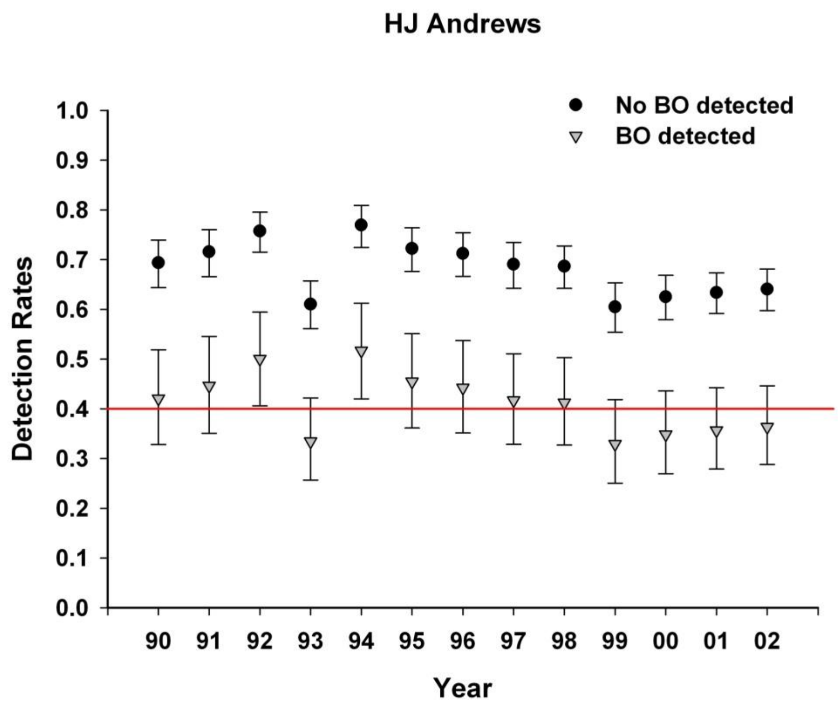
a).



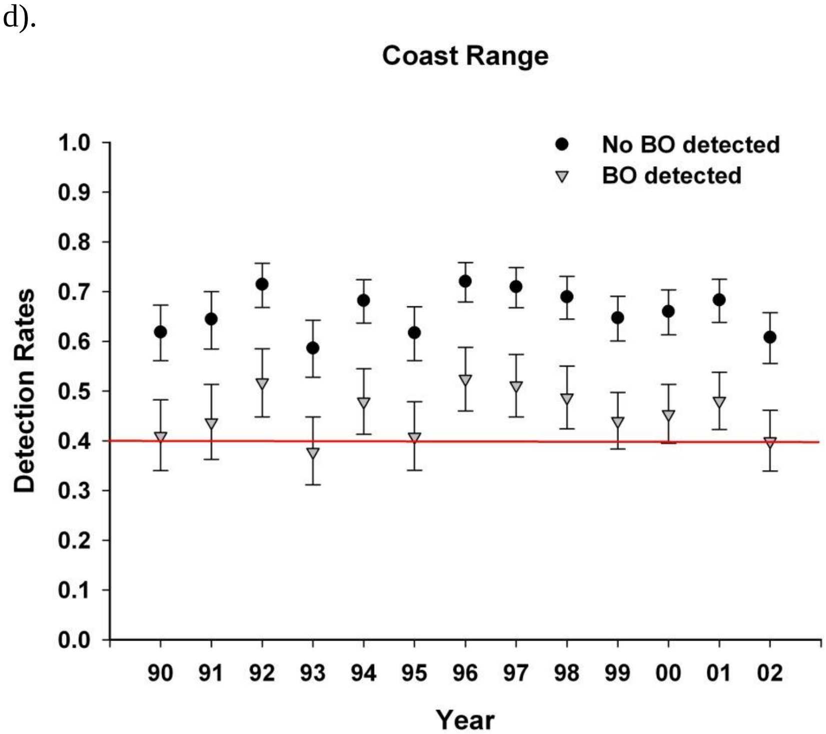
b).



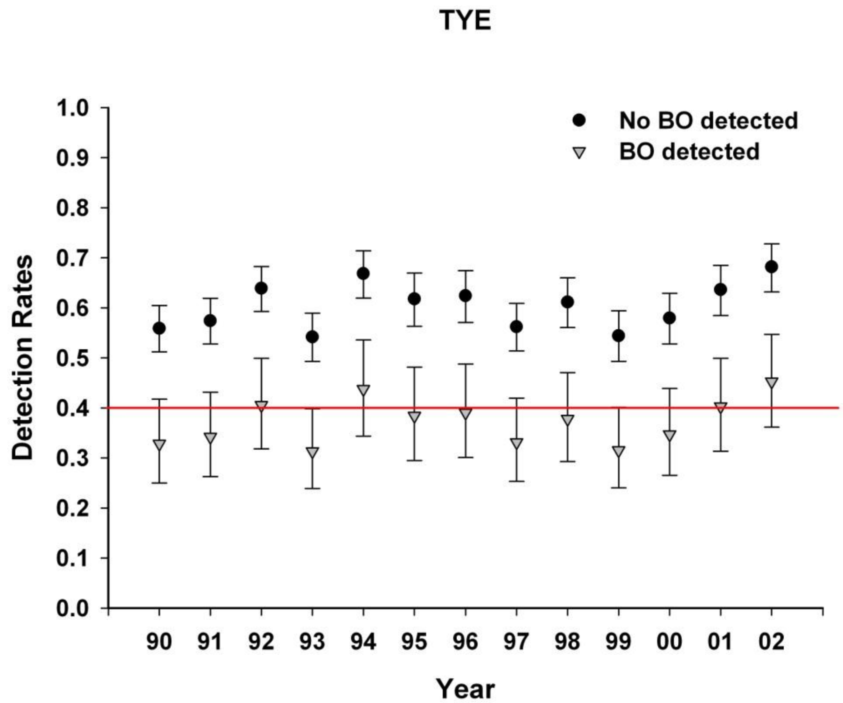
c).


HJ Andrews
No BO detected
BO detected
Detection Rates
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
90
91
92
93
94
95
96
97
98
99
00
01
02
Year

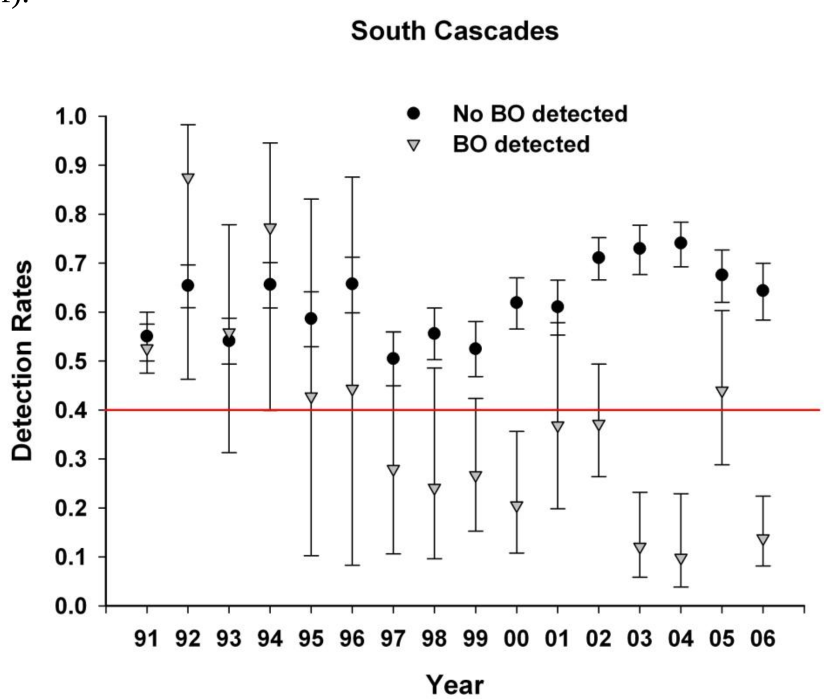
d).


Coast Range
No BO detected
BO detected
Detection Rates
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
90
91
92
93
94
95
96
97
98
99
00
01
02
Year

e).

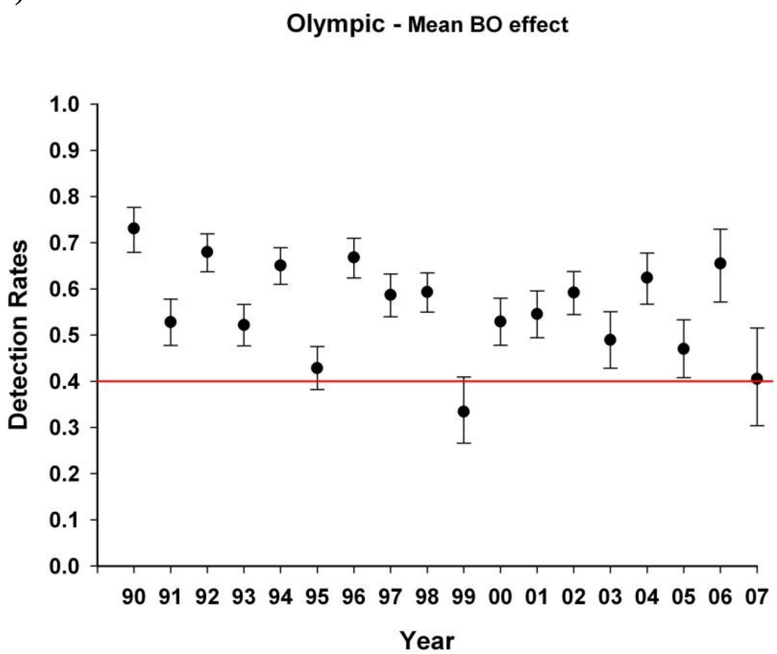

TYE
No BO detected
BO detected
Detection Rates
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
90
91
92
93
94
95
96
97
98
99
00
01
02
Year

f).

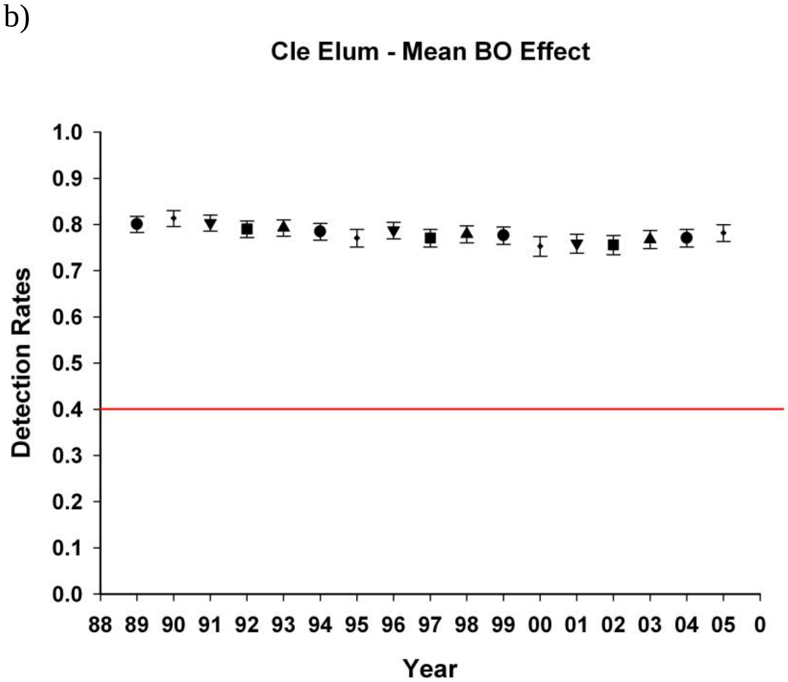

South Cascades
No BO detected
BO detected
Detection Rates
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
Year

Appendix Figure 3: Detection rate estimates with 95% confidence limits from the best models for a) Olympic, b) Cle Elum, c) HJ Andrews, d) Coast Range, e) Tyee, and f) South Cascades study areas. Estimates were generated for the mean response given the total proportion of territories where barred owls were detected across the entire study area (MN) each year. Red line reflects the minimum detection rate required for the 6-visit per year protocol to result in a 95% overall probability of detecting a spotted owl if present.

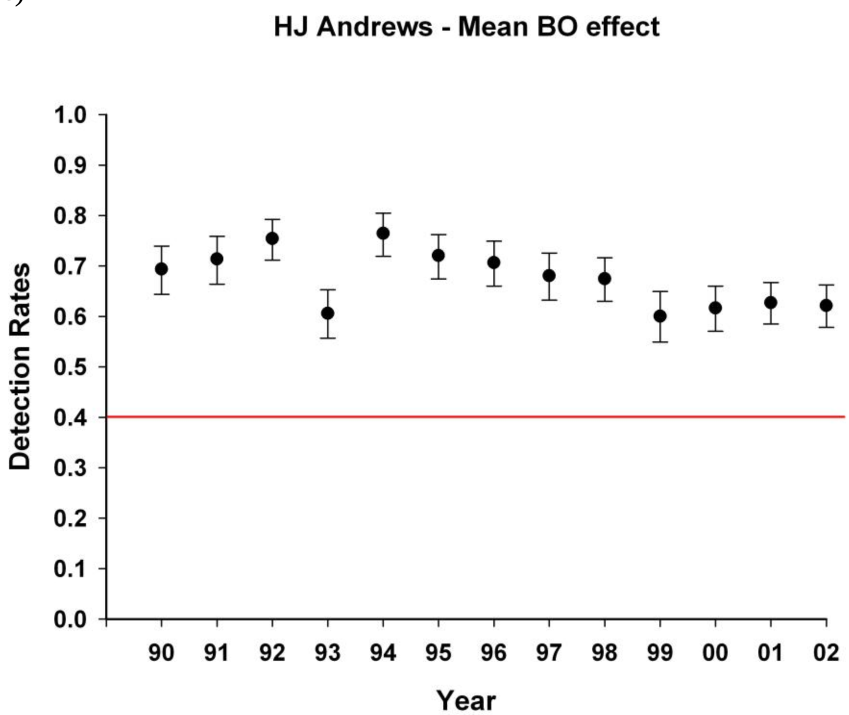
a)



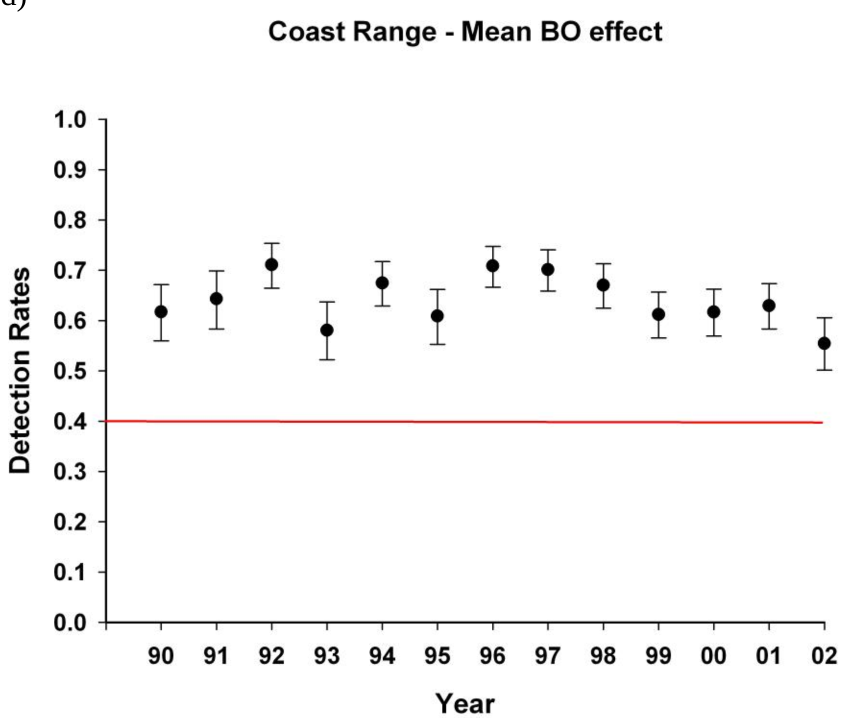
b)



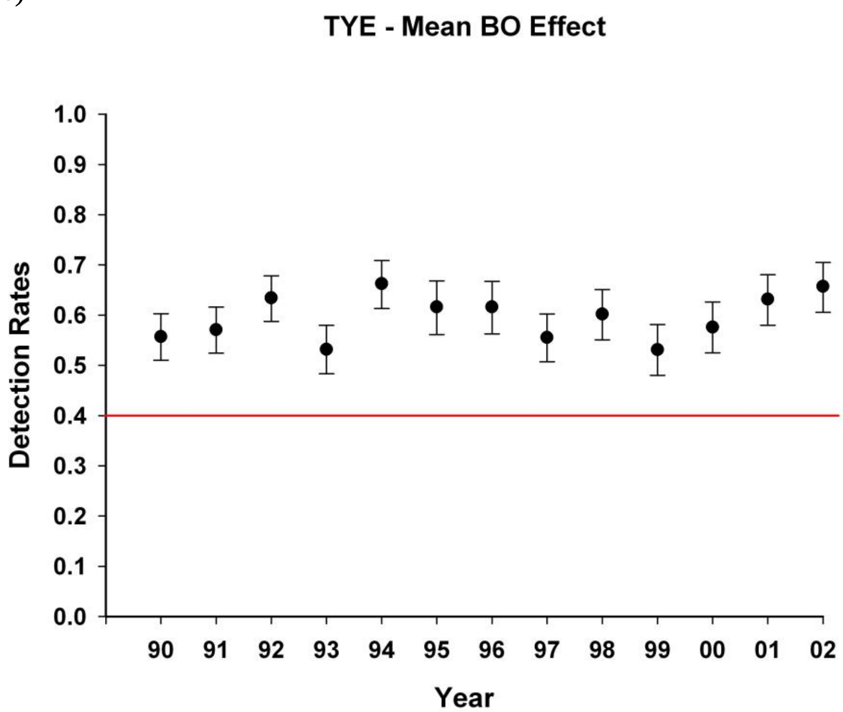
c)


HJ Andrews - Mean BO effect
Detection Rates
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
90 91 92 93 94 95 96 97 98 99 00 01 02
Year

d)


Coast Range - Mean BO effect
Detection Rates
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
90 91 92 93 94 95 96 97 98 99 00 01 02
Year

e)


TYE - Mean BO Effect
Detection Rates
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
90
91
92
93
94
95
96
97
98
99
00
01
02
Year

f)

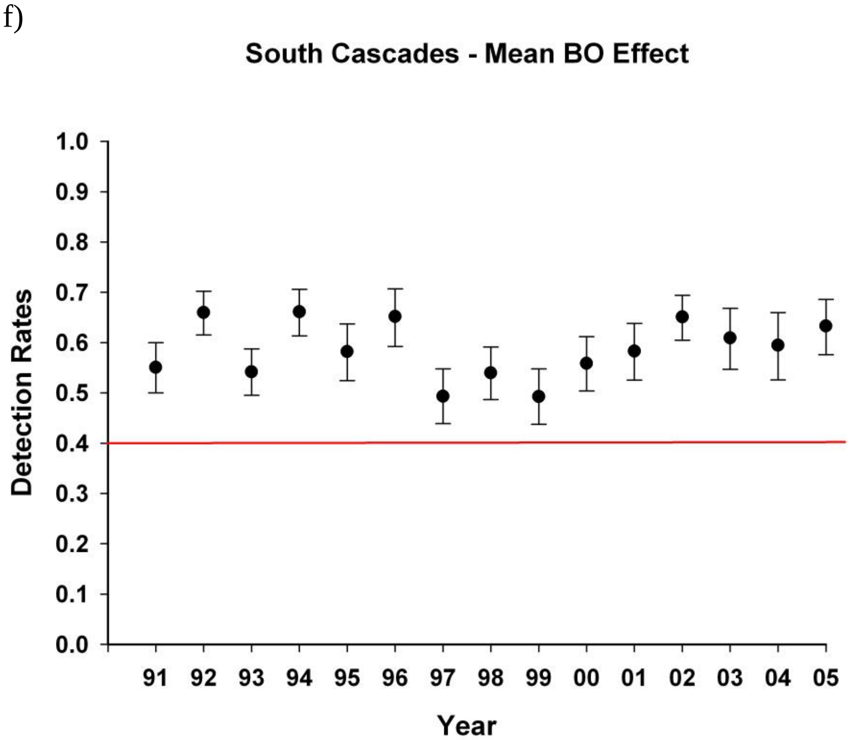
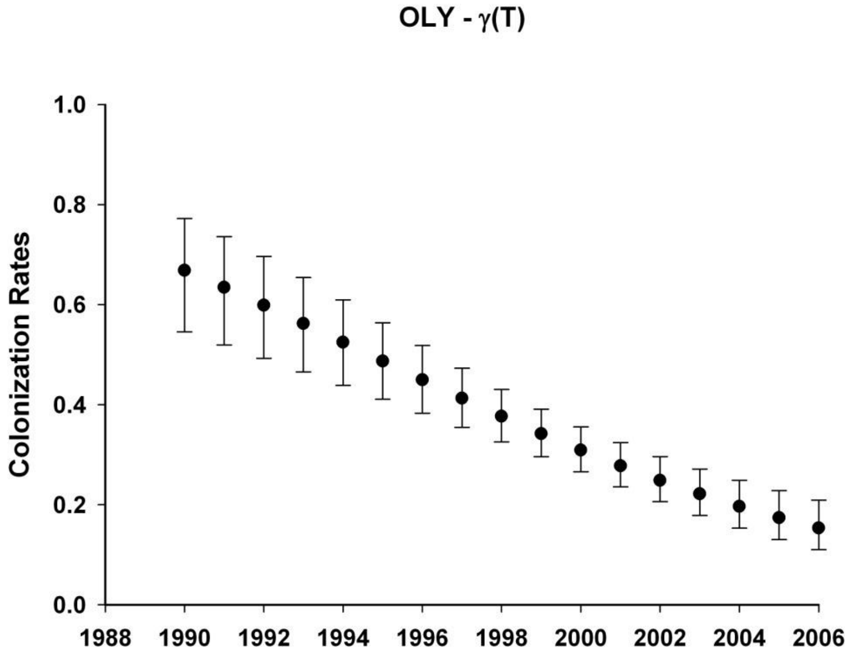
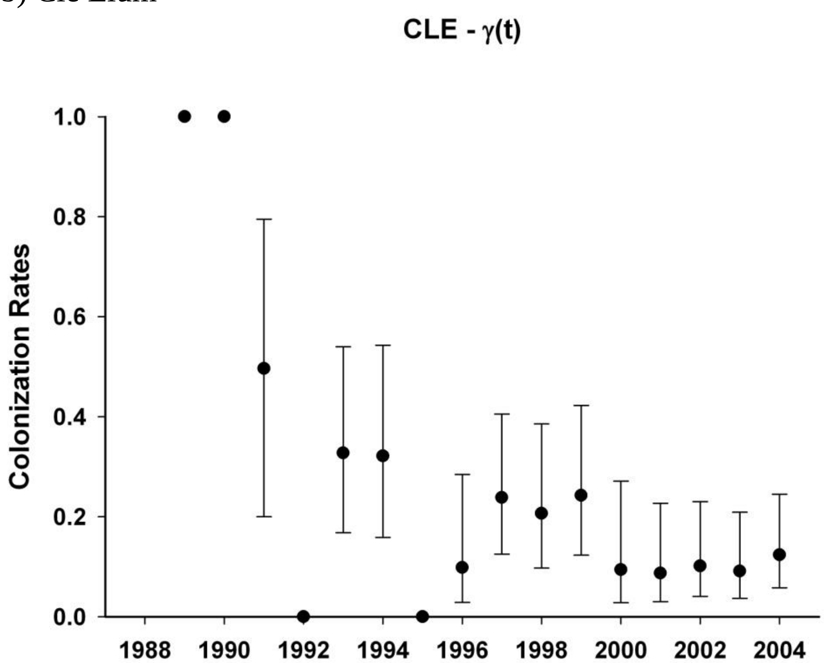

South Cascades - Mean BO Effect
Detection Rates
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
Year

Figure 4: Estimates of colonization rates with 95% confidence limits from the best models for a) Olympic, b) Cle Elum, c) HJ Andrews and Tyee, d) Coast Range, and e) South Cascades study areas.

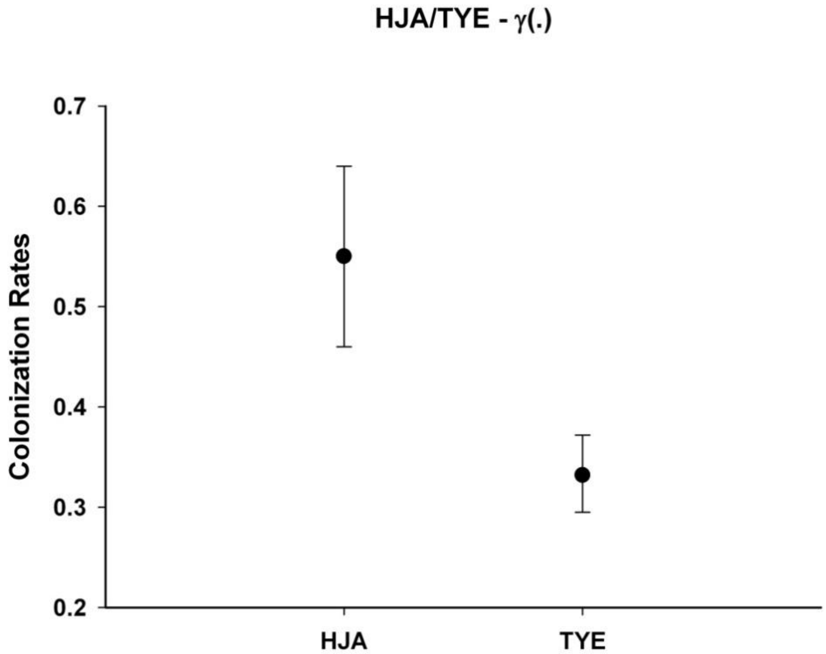
a) Olympic



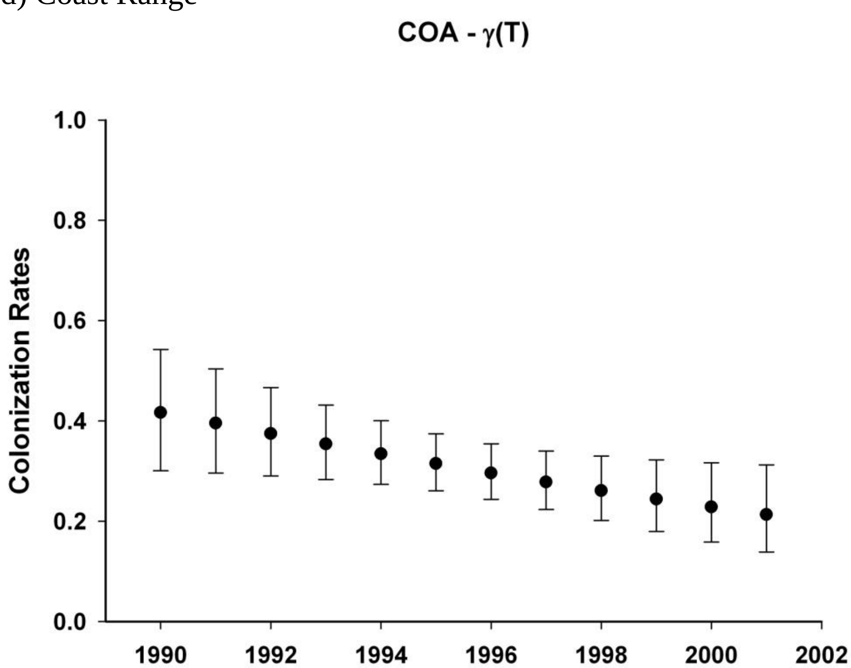
b) Cle Elum



c) HJ Andrews (HJA) and Tyee (TYE)



d) Coast Range



e) South Cascades

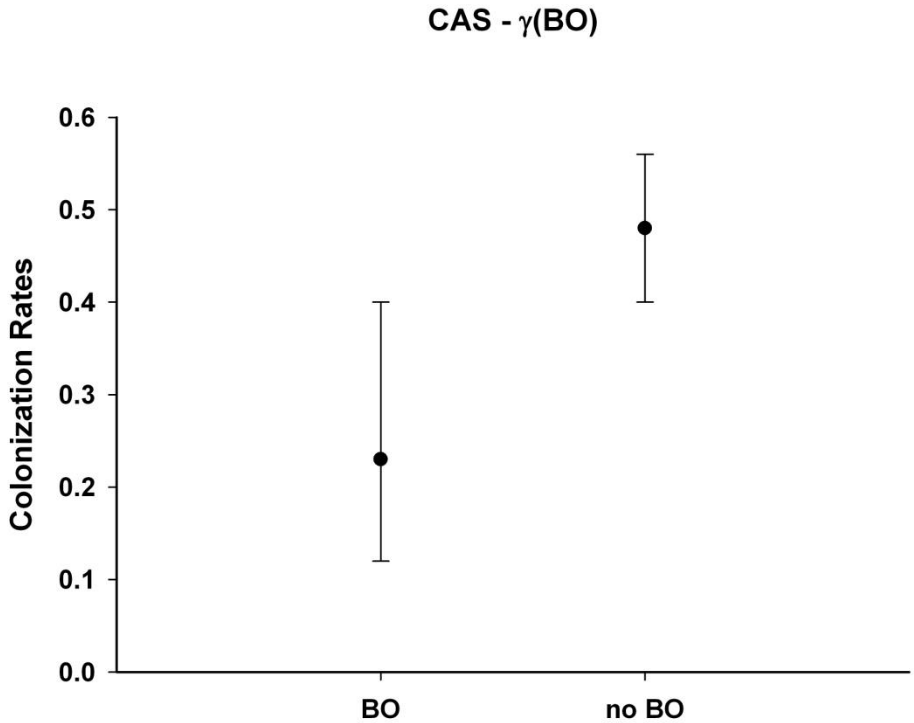
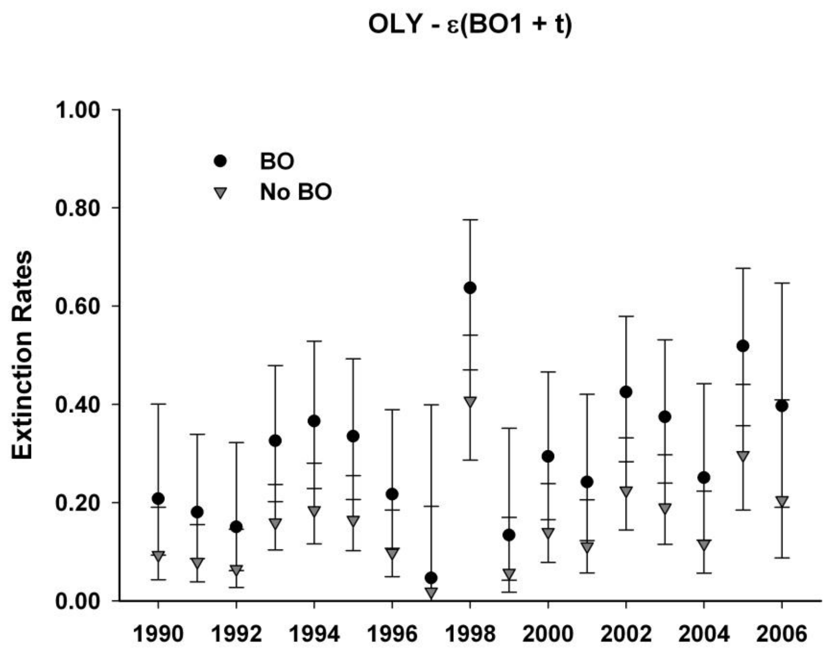
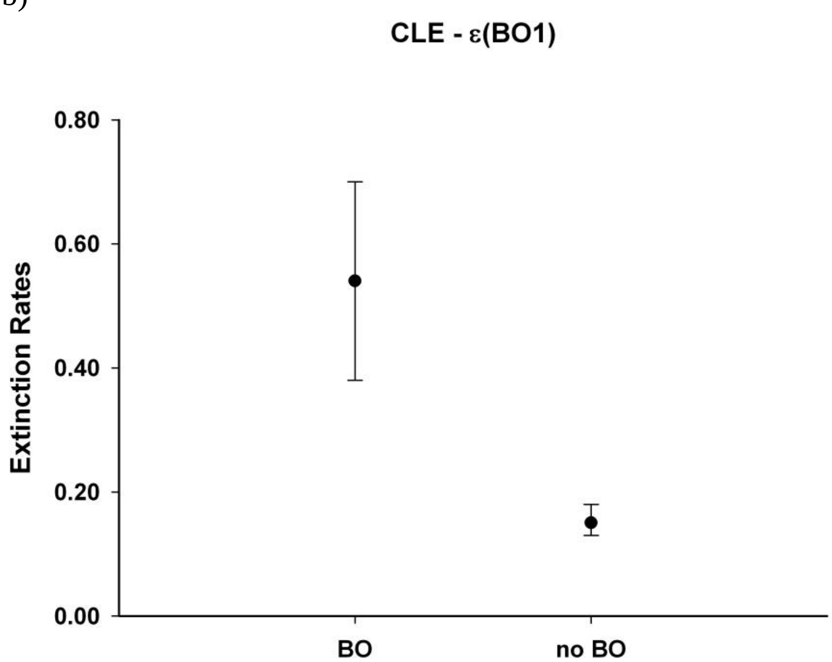


Figure 5: Estimates of extinction rates with 95% confidence limits from the best models for a) Olympic, b) Cle Elum, c) HJ Andrews, d) Coast Range, e) Tyee, and f) South Cascades study areas.

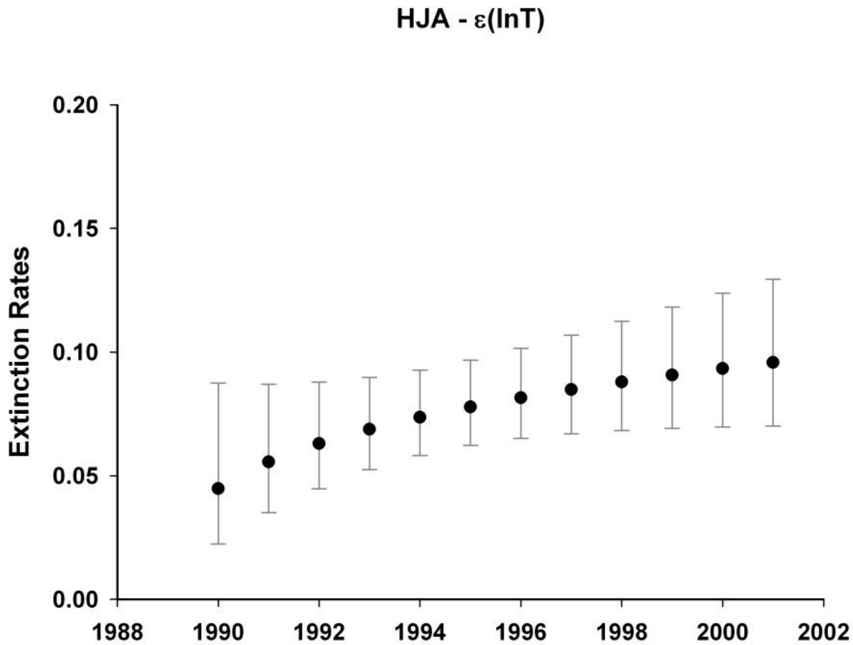
a)



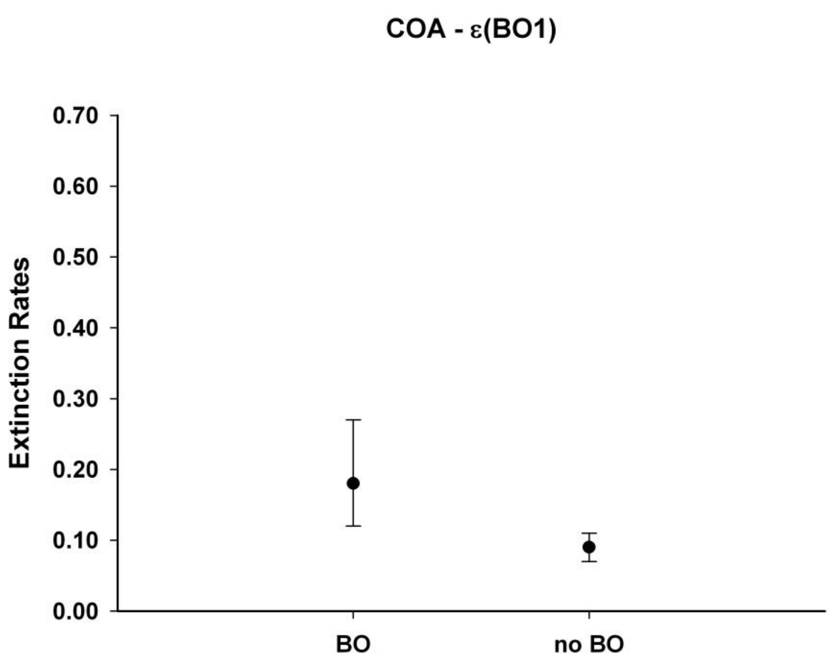
b)



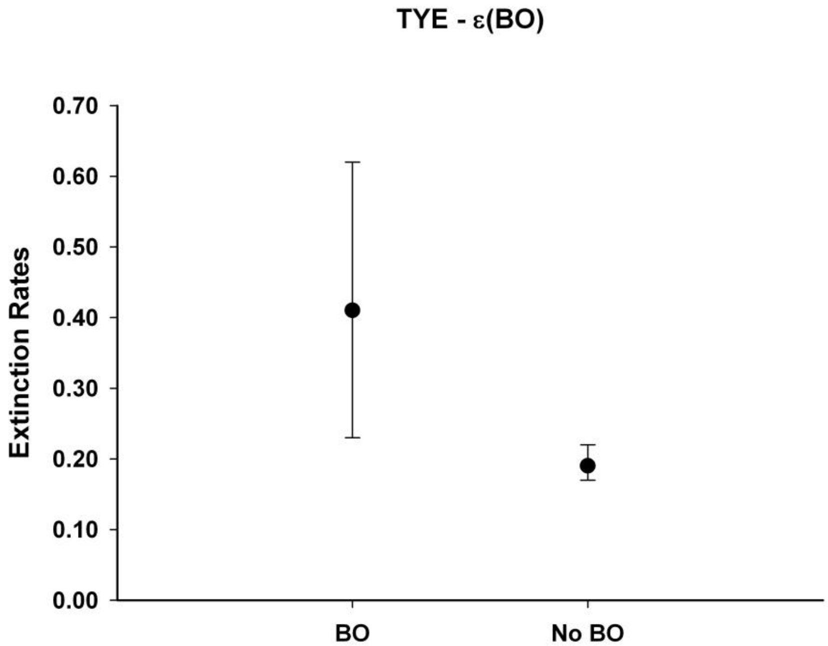
c)


HJA - ε(lnT)
Extinction Rates
0.20
0.15
0.10
0.05
0.00
1988
1990
1992
1994
1996
1998
2000
2002

d)


COA - ε(BO1)
Extinction Rates
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
BO
no BO

e)


TYE - ε(BO)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Extinction Rates
BO
No BO

f)

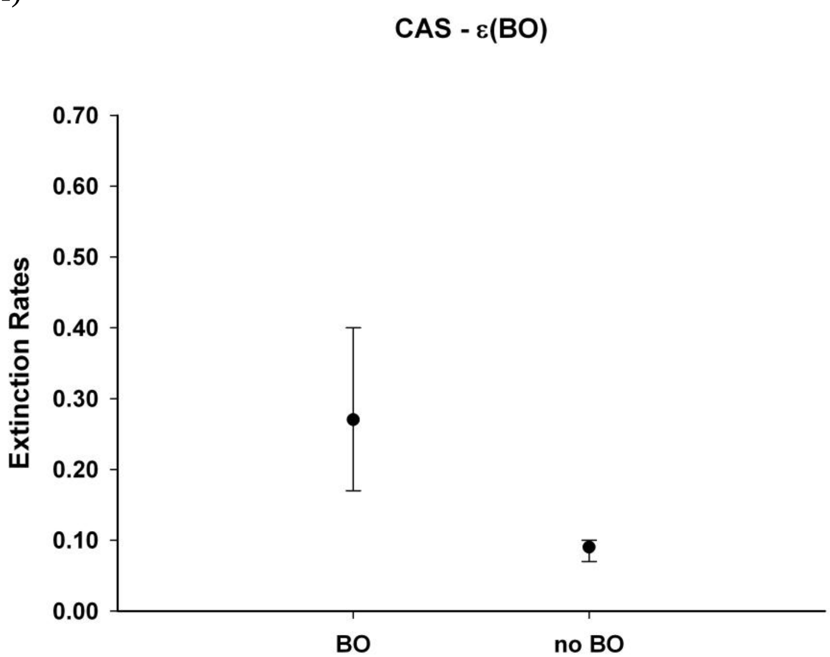
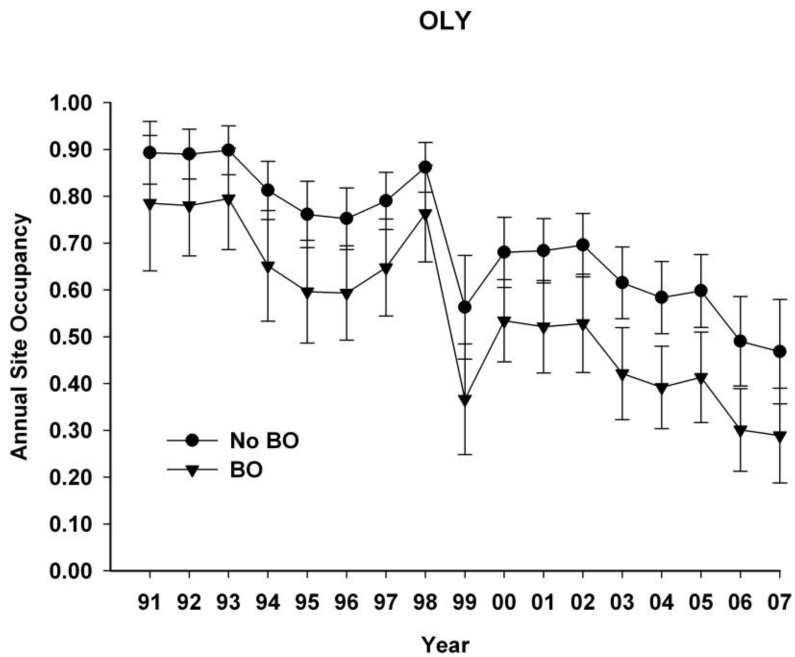
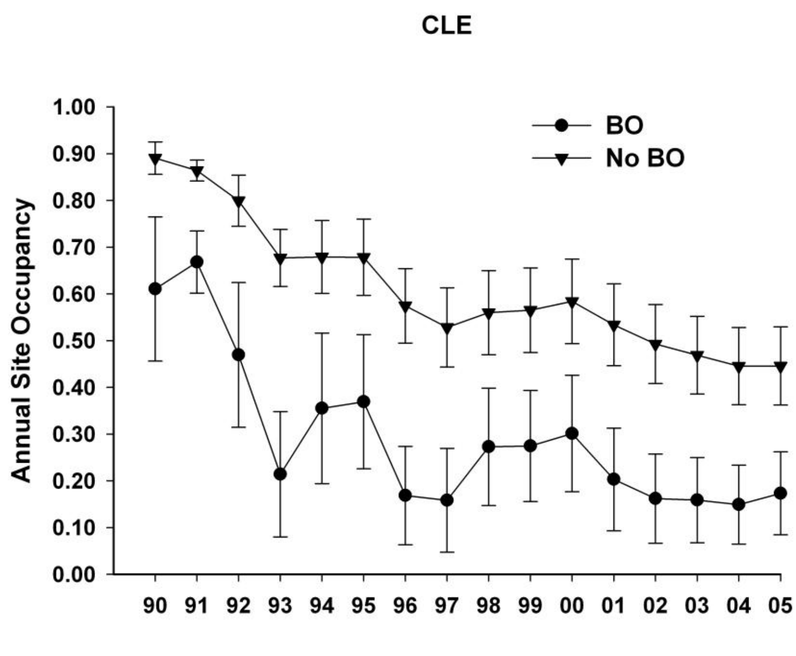

CAS - ε(BO)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Extinction Rates
BO
no BO

Figure 6: Estimates of annual site occupancy from the best models for a) Olympic, b) Cle Elum, c) HJ Andrews, d) Coast Range, e) Tyee, and f) South Cascades. Annual estimates were generated for each year when barred owls were detected (BO) and when barred owls were not detected (No BO).

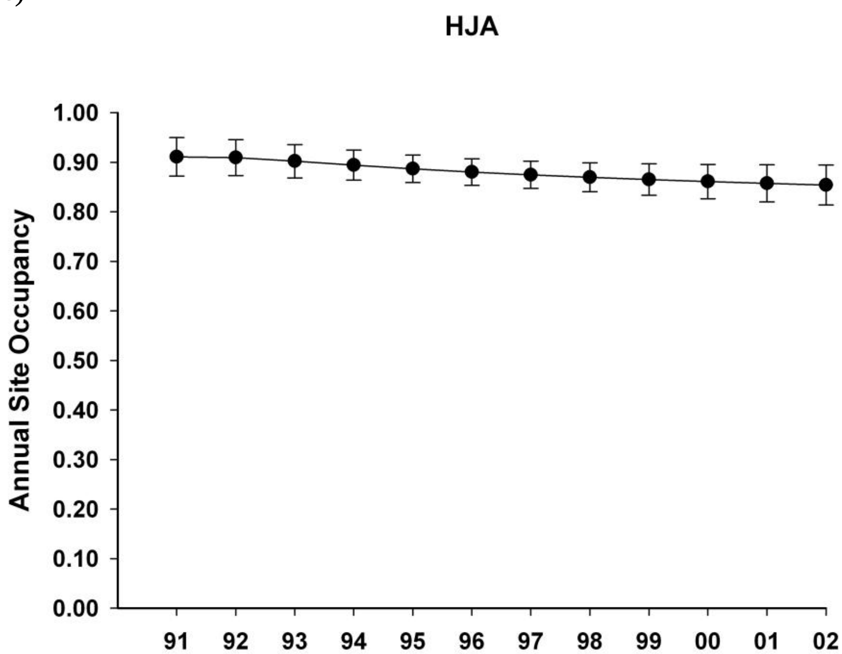
a)



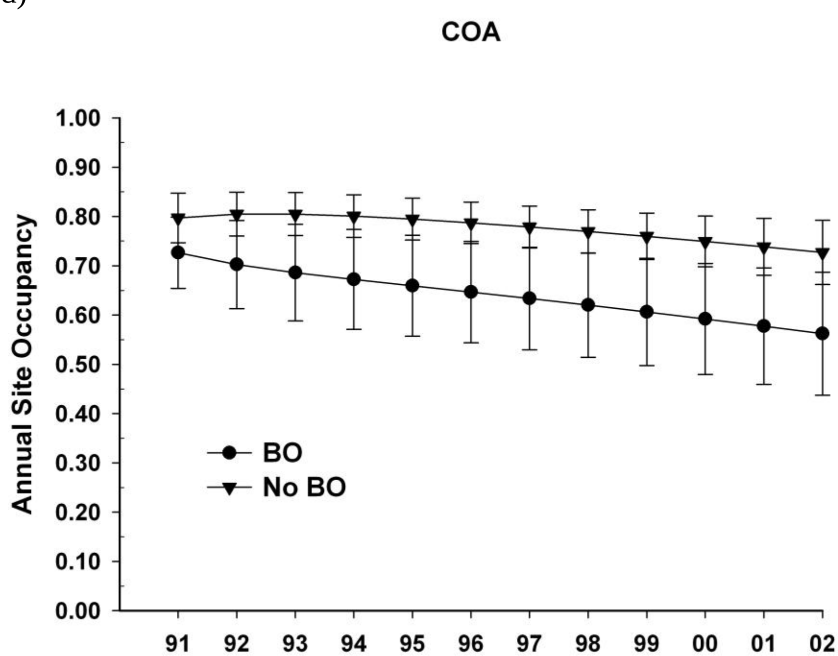
b)



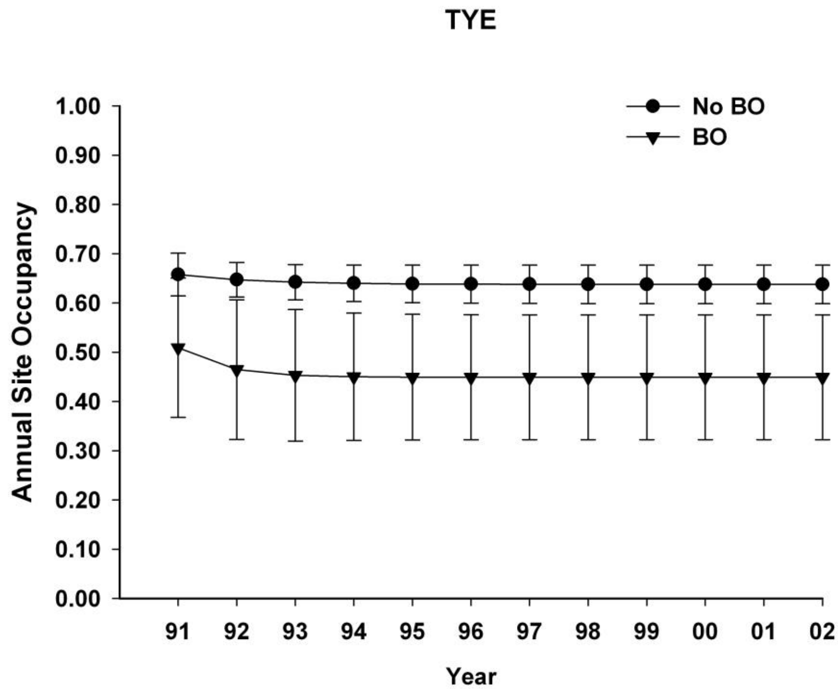
c)


HJA
Annual Site Occupancy
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
91
92
93
94
95
96
97
98
99
00
01
02

d)


COA
Annual Site Occupancy
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
BO
No BO
91
92
93
94
95
96
97
98
99
00
01
02

e)


TYE
No BO
BO
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Annual Site Occupancy
91
92
93
94
95
96
97
98
99
00
01
02
Year

f)

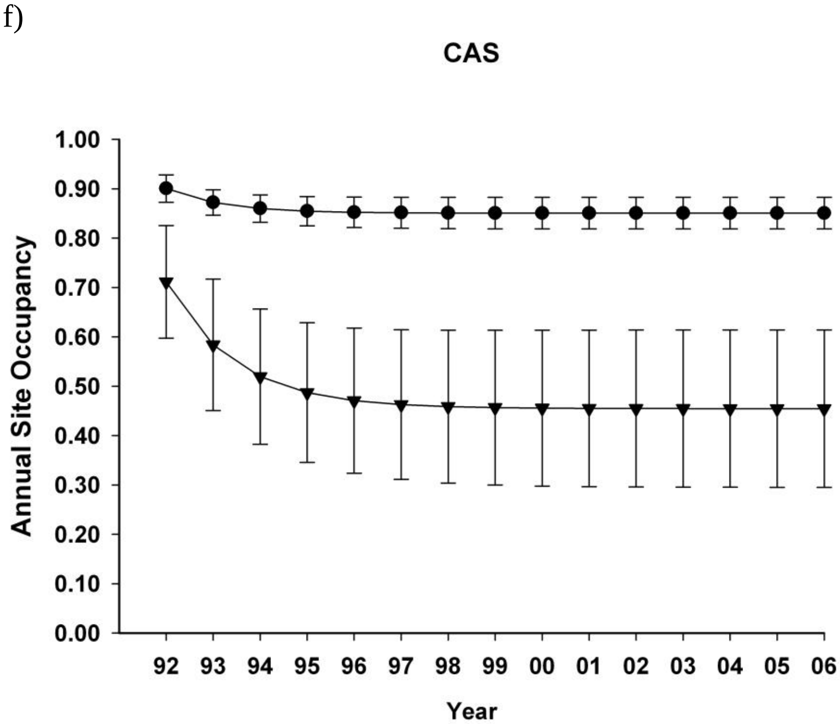
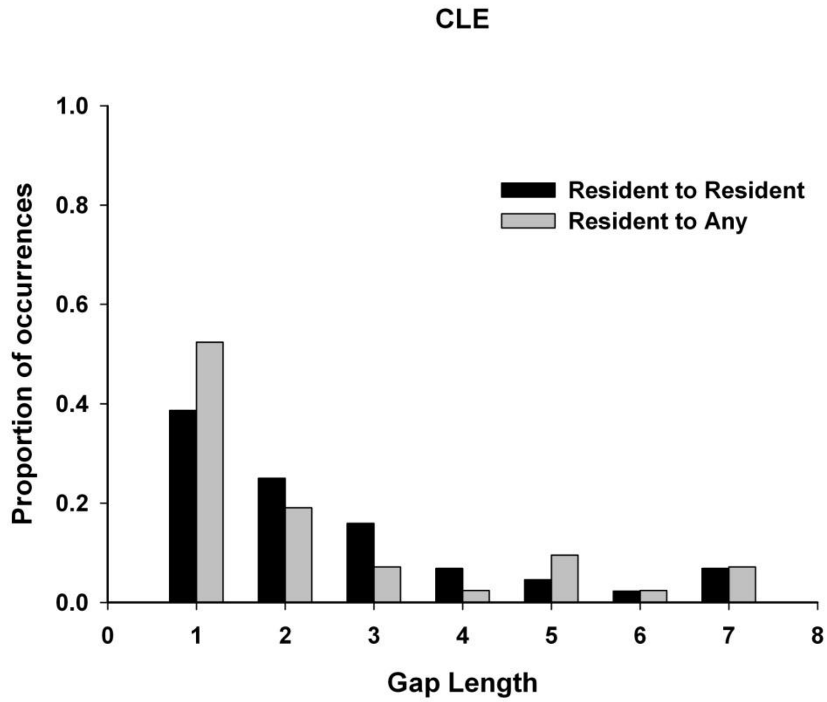
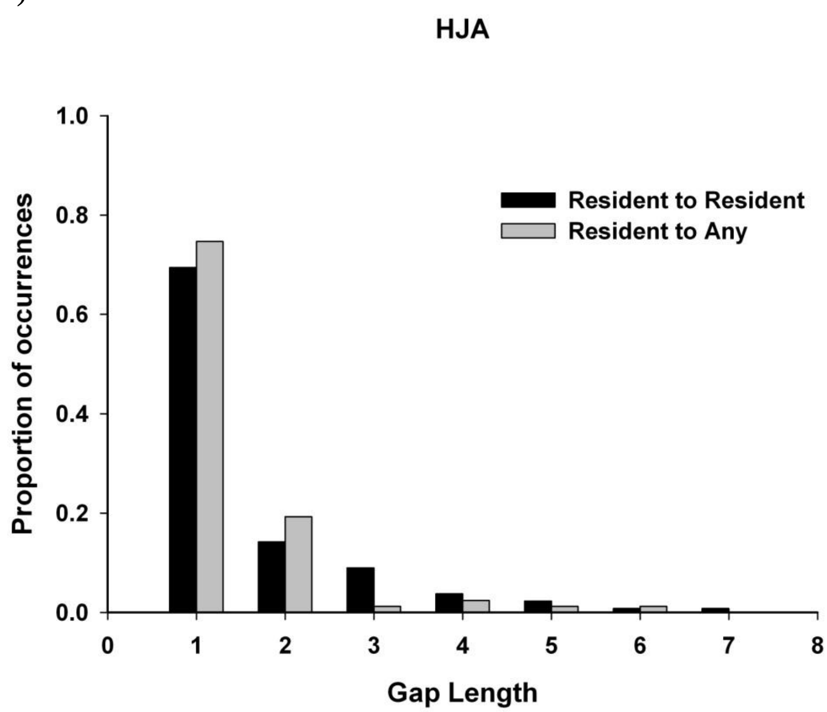

CAS
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Annual Site Occupancy
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
Year

Figure 7: The proportion of total contiguous "gaps" in northern spotted owl detections across all territories and all years, by gap length for a) Cle Elum, b) HJ Andrews, c) Coast Range, d) Tyee, e) Klamath and f) South Cascades study areas.

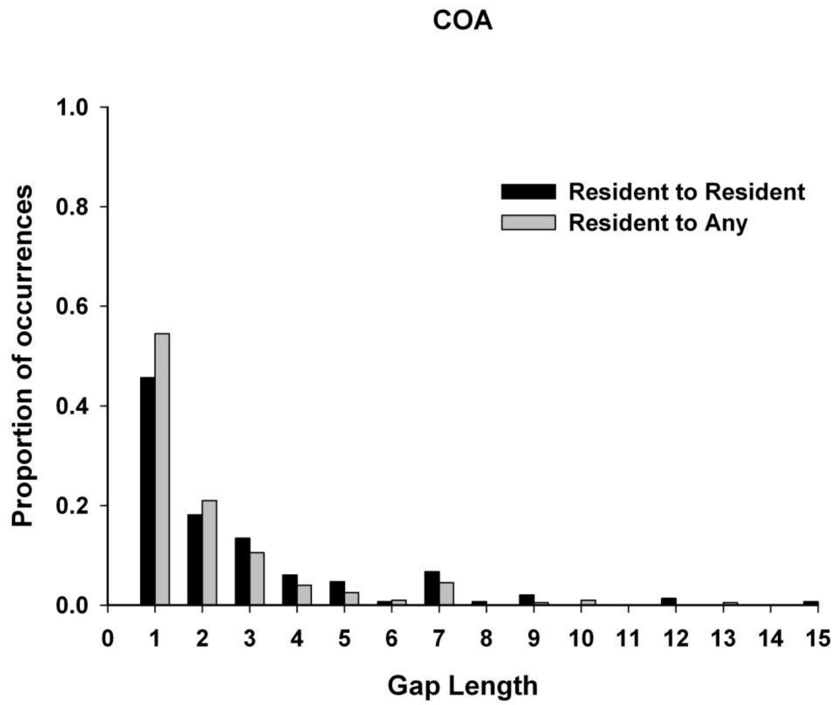
a) Cle Elum



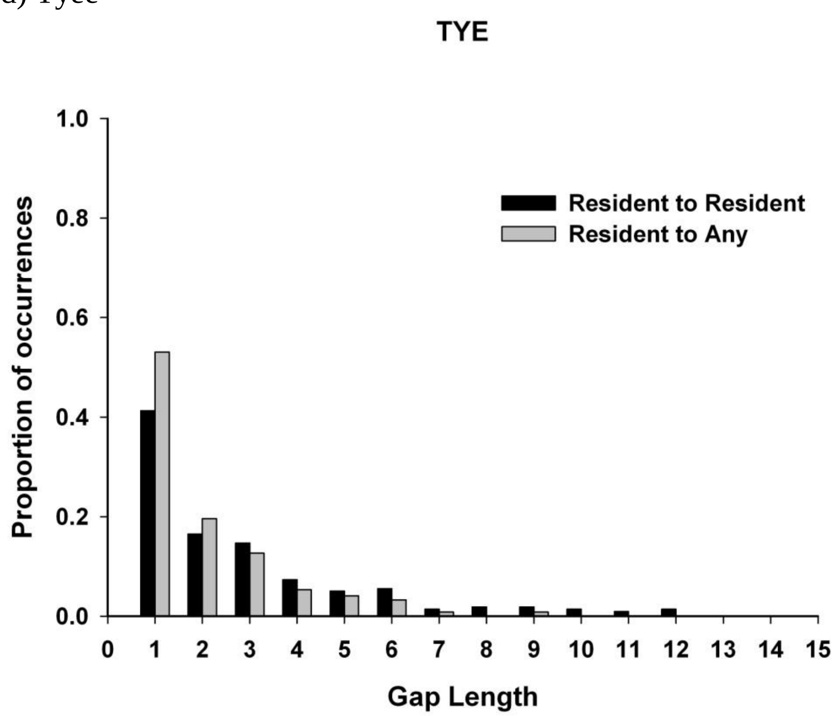
b) HJ Andrews



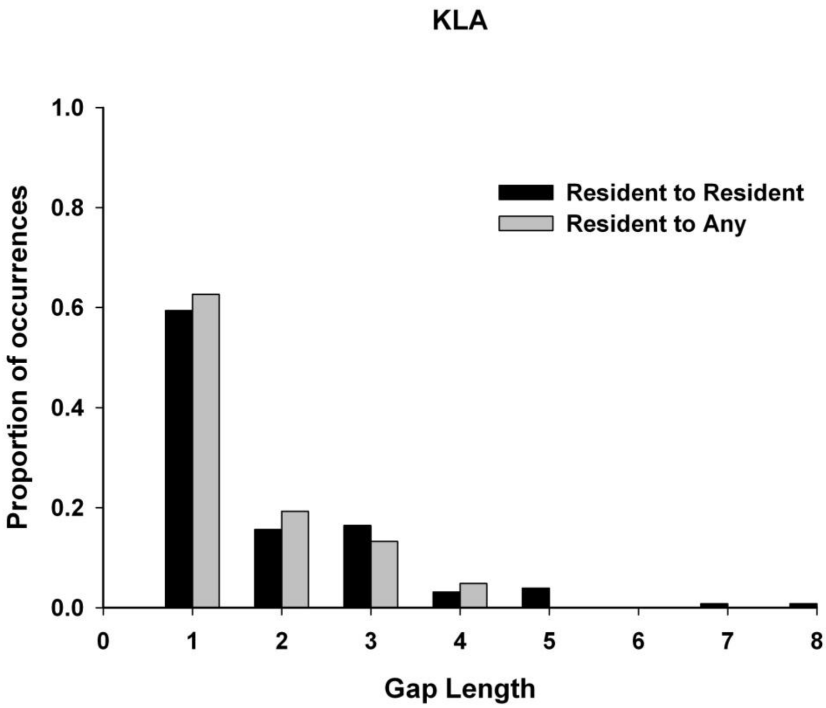
c) Coast Range



d) Tyee



e) Klamath



f) South Cascades

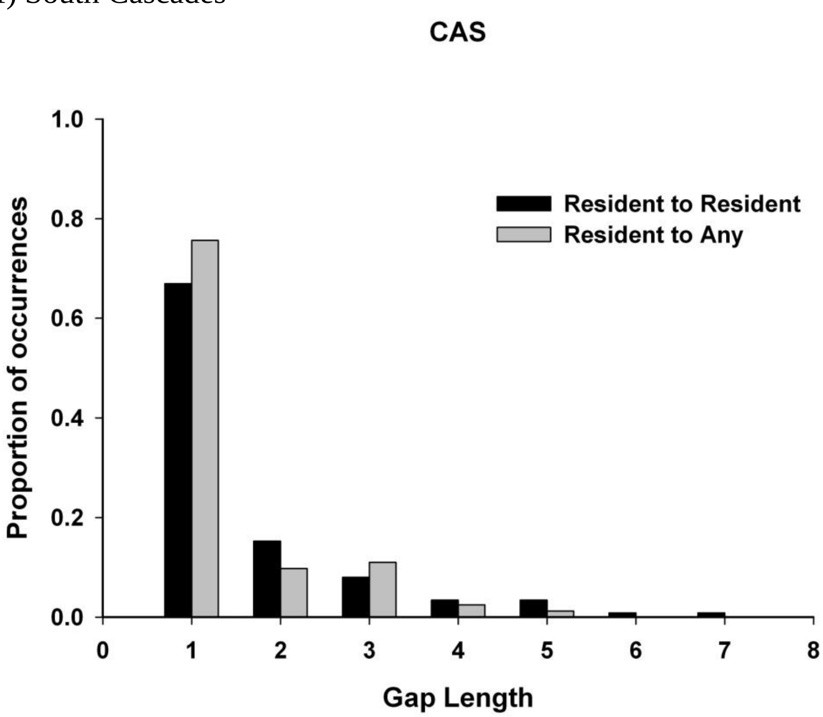
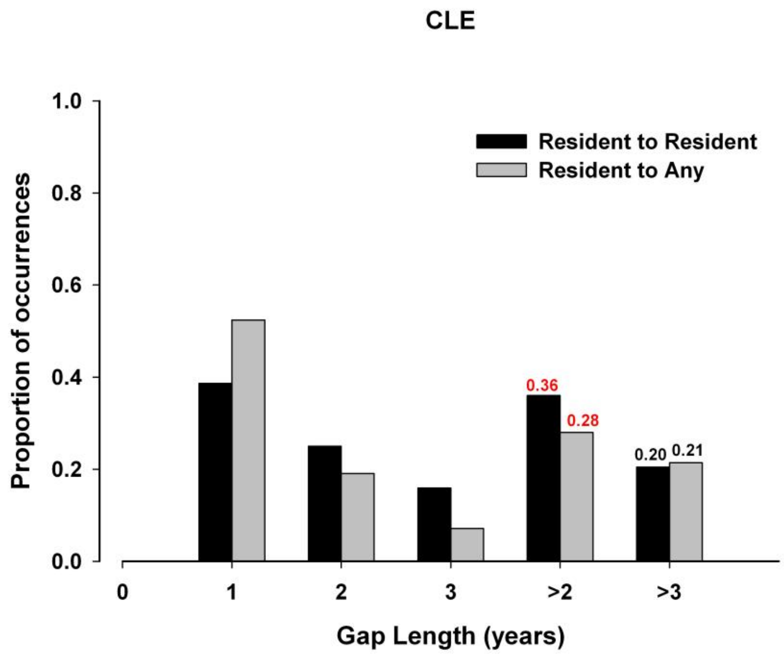
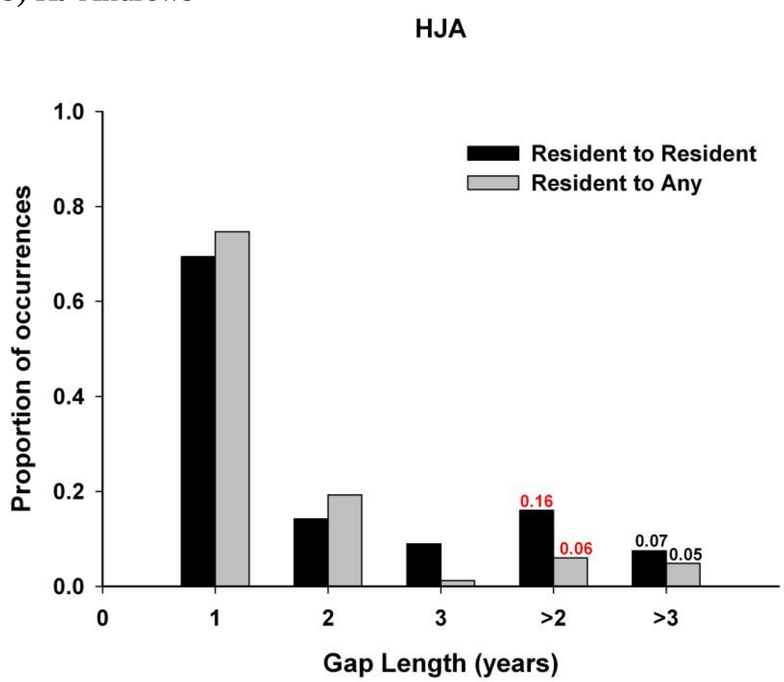


Figure 8: The proportion of total contiguous "gaps" in northern spotted owl detections across all territories and all years, by 4 gap length categories: 1-year, 2-years, 3-years, all gaps >2 and >3 years for a) Cle Elum, b) HJ Andrews, c) Coast Range, d) Tyee, e) Klamath and f) South Cascades study areas.

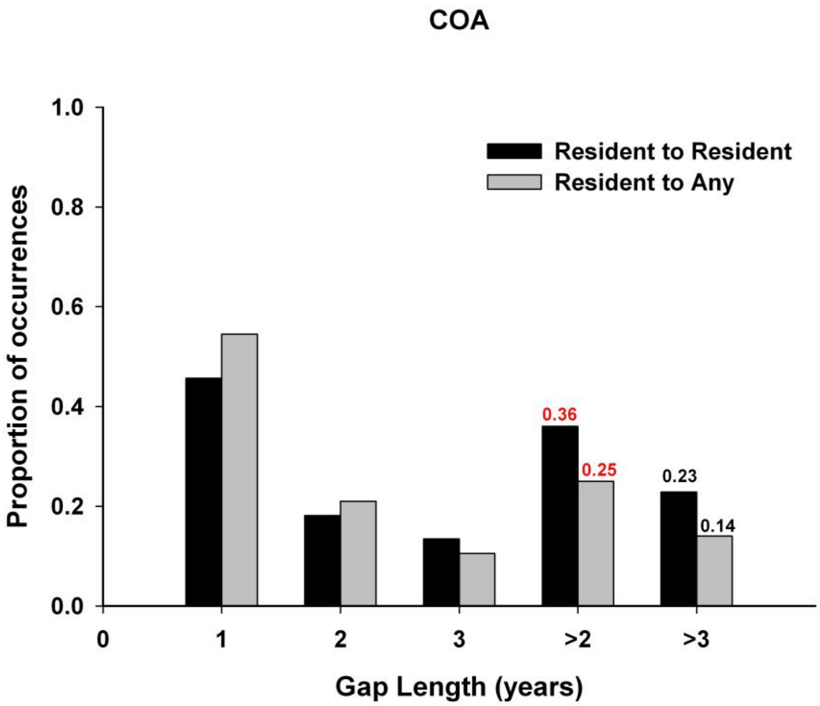
a) Cle Elum



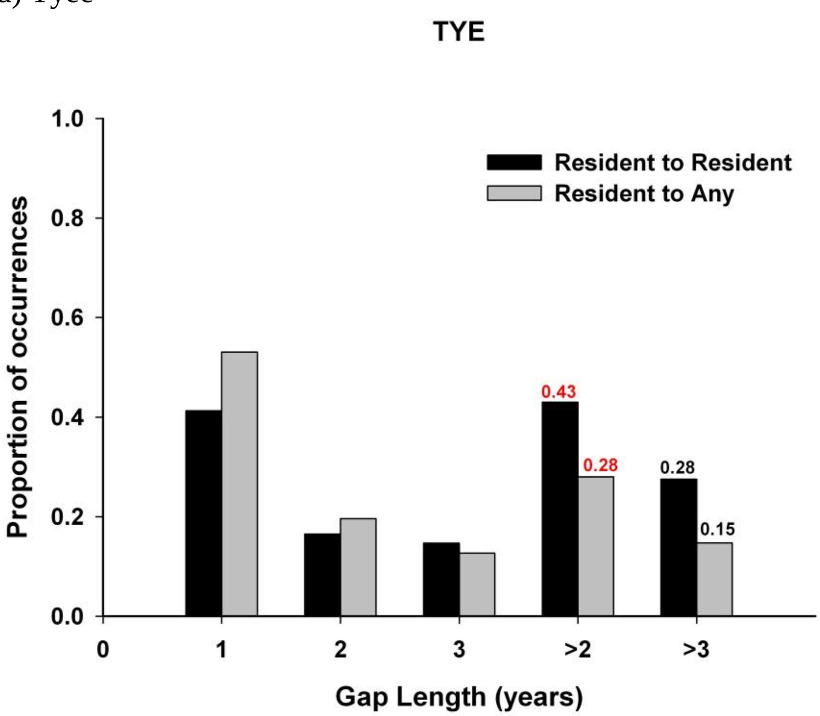
b) HJ Andrews



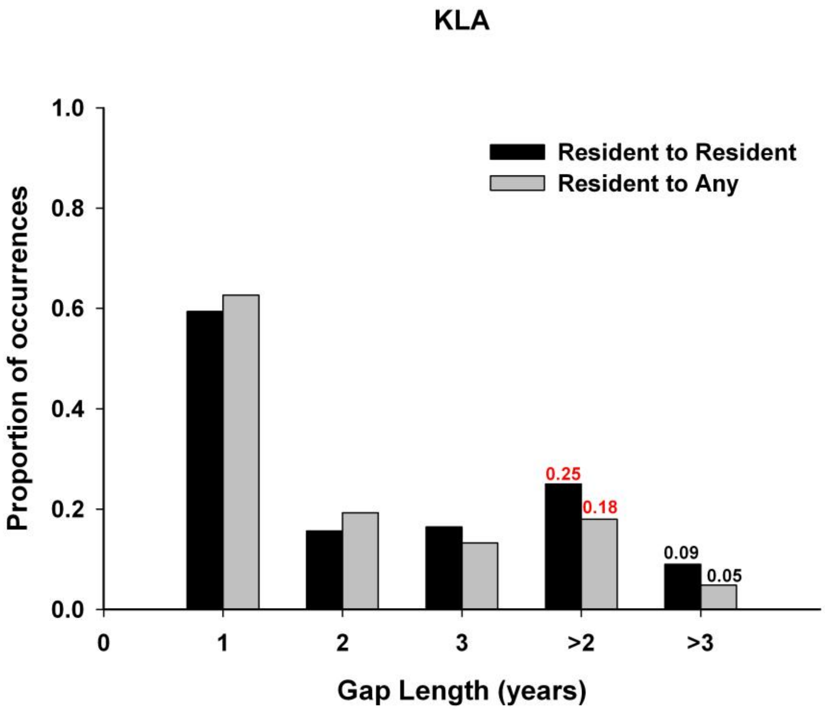
c) Coast Range



d) Tyee



e) Klamath



f) South Cascades